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GENERAL ELECTRIC Review

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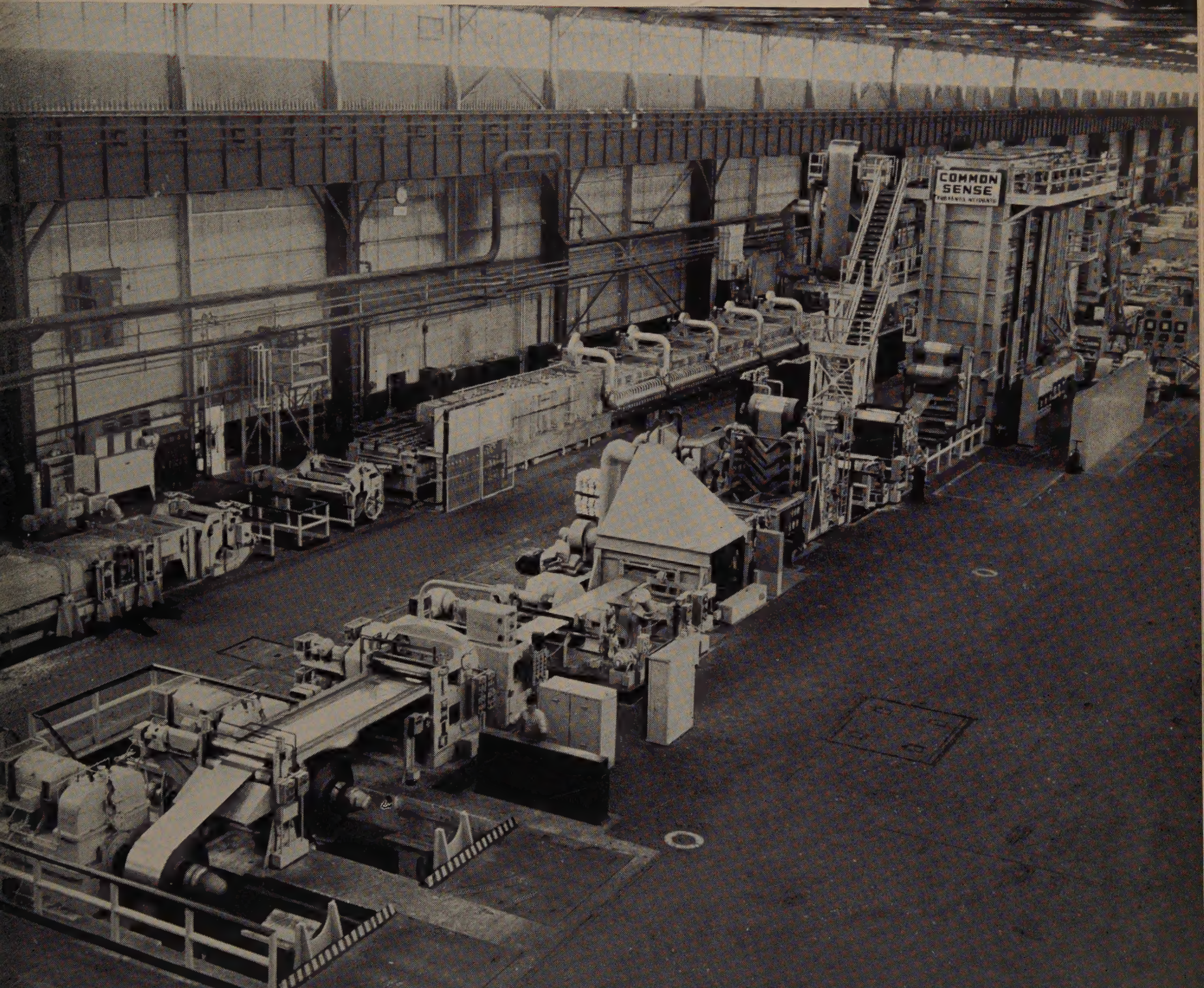

December, 1949

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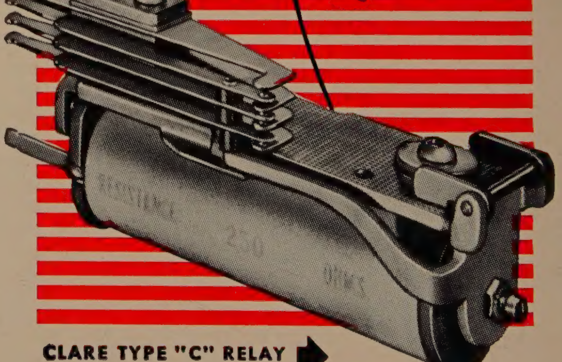

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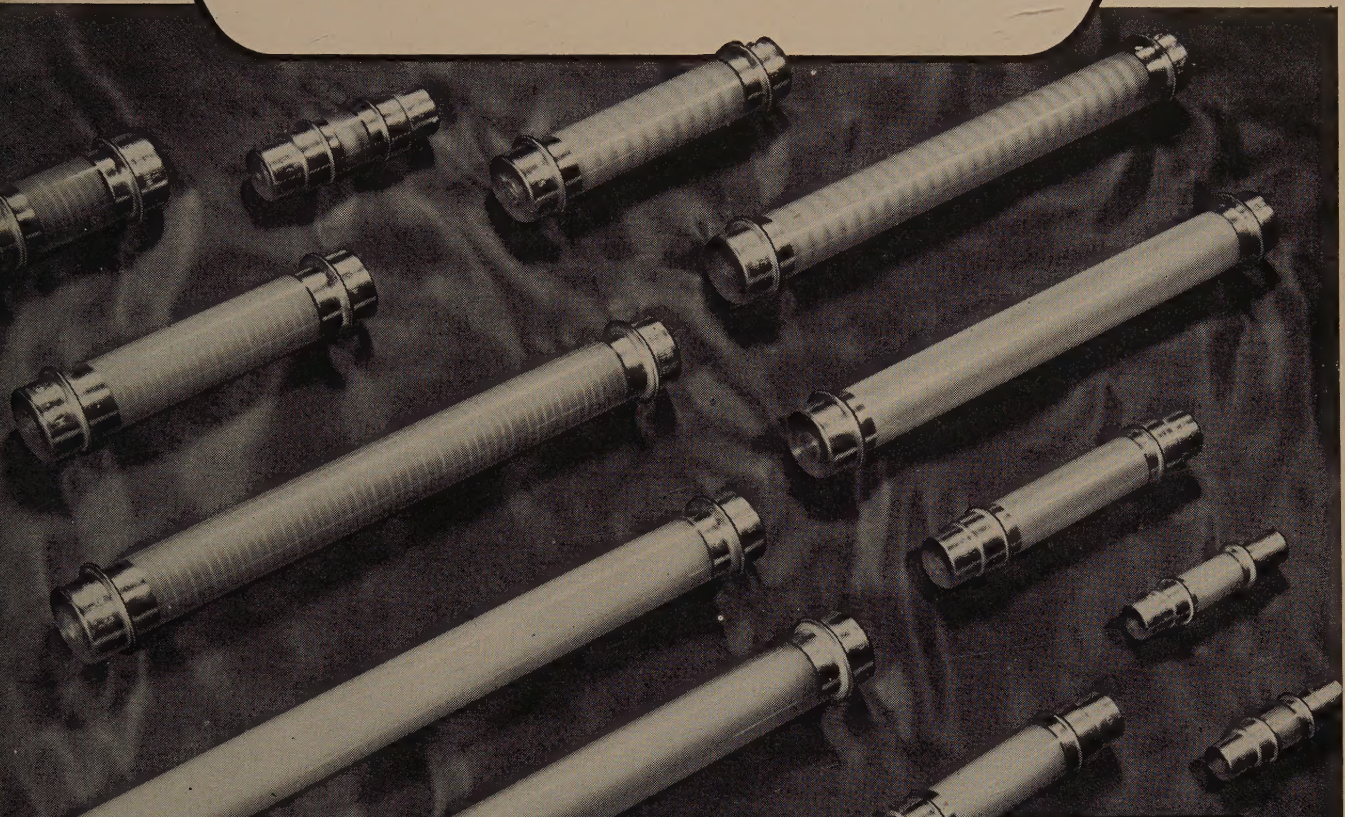

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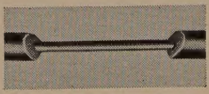

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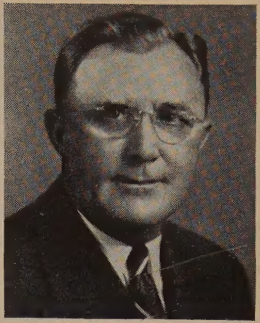
WHAT INDUSTRY EXPECTS OF THE ENGINEER

First: What is industry? It is broader than we customarily think. It is the organized striving of millions of fellow citizens to improve their welfare by application of creative talents and constructive efforts. From engineers, that industry expects not only technical achievement but also the application of orderly thinking and vision to human problems



By CHARLES E. WILSON
President, General Electric Company

BY ITS very nature, the question posed by the subject of this address* is broadly philosophical, and if we who try to answer it do not take extreme care, we will give it only a philosophical answer. Perhaps it may be thought that such consideration would not be entirely out of place here but I do not believe that is the type of answer desired. We should not, I feel, be afraid of broad or deep subjects so long as our approach is a practical one. The aircraft pilot may refer with some scorn to ships or projects which do not get off the ground, but he is able to do so principally because some aeronautical engineer has done the groundwork for him. So I should like, in considering what industry expects of the engineer, to stay as close to the ground as possible and leave the soaring to other times and other groups.

INDUSTRY DEFINED

One of the finest ways to come a cropper with this subject would be to proceed without defining what we mean by "industry." It is a word that means many things to many men, not all good, but most of them familiar. It is a sort of feather bed of a word that can be punched into whatever shape the puncher most desires to suit his ends, depending on whether he wants to smother somebody with it, or just lie down. Our contemporaries on the militant side of organized labor, and on the political side of government, are exponents of the smothering technique, while those of us who look on industry as a vast structure in which we make our living are more likely to lie down, serene in our assurance that we are understood.

In a climate such as we have enjoyed since the war it becomes more and more imperative that we make everybody—every child and every adult, every teacher and writer and worker and stockholder and customer—understand that industry is a house in which dwells every man and woman who is involved in any way in the development, production, and distribution of goods and services. It is labor, it is management, it is research and engineering, it is investment, and it is sales. To some degree it is just about everybody you know—and not just a small, selfish, rich, and aged group of Republicans.

For every one of us who believes that what happens to America—and therefore to the world—must be a direct result of the efficiency and productiveness and leadership of our own competitive economy, the hard and constant fight consists of this day-by-day campaign to teach our people that industry is not a political party, that it is not a special interest, that it is not an antisocial force. Rather it is the organized striving of millions of our fellow citizens, the harnessing of their brainpower and their labor, the mustering of their needs and desires, the enrollment of their ambition and their accountability, to the end that they will be better fed, better housed, better secured against disaster, better informed, and inspired by a true respect for their own powers and their own dignity. That is industry, and to me that is not a visionary or fuzzy description, but a down-to-earth practical description.

Within such a framework it is possible for us to pick out any kind and size of undertaking, where men have come together to make and sell a product, a service, or an idea, and say *this* is a part of American industry. I have no difficulty in including the farmer in such a category, as the farmer certainly is one of the earliest and best examples in our history of the capitalist system, its risks, and its rewards. The farmer, like the manufacturer, has long been dependent upon the engineer and the research scientist for the extension of his facilities, for new tools, for improved methods, and for broadened markets. It goes without saying that industry will continue to expect these things of the engineer, mostly as a matter of course, since they are his stock in trade and his reason for existence. To the extent that the individual engineer is able to contribute them he will be successful in his profession.

RESPONSIBILITY OF THE ENGINEER

So far we have spoken of results, in terms of substantial progress, but the engineering mind is expected to contribute something else to our civilization, and that something is orderly thinking. It may be possible to write a novel or paint a picture or evoke man's genius for creation in some other form in a haphazard or disorderly manner. But it is hardly possible to bridge a river by starting in the middle of the stream, or to build a building from the top down, and from my own experience I am quite certain that no one in his right mind begins to lay out a production line on a factory

---

*An address by Mr. Wilson on the occasion of the 125th anniversary of the Rensselaer Polytechnic Institute, Troy, (N. Y.), Oct. 14, 1949.

This article is so paged that, without mutilating other articles, it can be readily removed for filing as a group of full-size consecutive pages.—EDITOR

floor until after it has been planned on paper. So there is an orderly way of approaching most scientific and engineering problems—and there is no other way. Industry expects rational and orderly thinking from the engineering mind, as well as concrete achievements. It expects solid foundations, intelligible plans for action, and good structural judgment.

There is one more common thing that we all expect from the engineer, even if we do not always get it, and that is vision, compounded equally of imagination and faith. Without this quality, the technically trained man is blind, a capable servant, a somewhat less than automatic machine. This is the true badge of the professional man, that he be not only learned but that he be able also to project his learning into the future.

Those are very specific qualities even though they appear to be generalities. There is nothing very new about any of them, because they are the common attributes of the engineering mind and the engineering method. They become critically important, however, when we think of them not just in terms of the end product—the bridge, the machine, the building—but in terms of the human being himself. It is precisely at this point, it seems to me, that we begin to get on new ground.

Up to now we have said that *industry* expected substantial progress, orderly thinking, and vision from the engineer. Actually that is what everybody expects from him. There is a new urgency in what industry must have from the engineer in any consideration of modern problems. Because he is all of these things, or aims to be, we expect much more. We expect him to apply his talents and his learning not alone to the mechanical and scientific complexes of our life, but to the social and economic complexes as well.

RESPONSIBILITY OF INDUSTRY

Industry—and now I am referring to the manufacturing industry—used to be in business to make money, as has been said elsewhere. But today—and especially if it is big industry—it has to make money in order to stay in business. That is not just a play on words, because it would be tragic to make a joke of something that is so difficult to do. This is a statement which accurately reflects many of the things that have been happening to us in the past twenty years.

In big business today there is no longer any of the godlike opportunity for making sweeping decisions that there once was. The General Electric Company, for example, is not the personal property of one man or several men, who can wake up some morning and, not liking the looks of things, can say: "We will close this plant." General Electric is the personal property of a quarter of a million stockholders, and many of these, even, are institutions representing other thousands of investors and dependents. These people and these institutions, having faith in many things but principally in the American system, have risked their capital and are entitled to continuity and responsibility of management and a fair return. A corporation such as ours is charged with staying in business for their sake.

General Electric directly provides employment for almost 200,000 persons. It is charged with the continuation of those jobs, at a fair rate of compensation, and with so managing its business that it can continue to provide opportunity and security for each of its families.

In every one of the hundred or more communities in which the Company operates it bears the additional responsibility of community stability.

Finally, the Company has literally millions of customers who are served through the efforts of independent wholesalers, retailers, agents, and others, and once more it is charged with the great responsibility of staying in business profitably, with good products and good service, for the sake of those thousands of smaller businesses.

Those are only the barest outlines of this vast integration of human effort and dependency in which a modern large corporation is involved. It has no right, and especially no moral right, to pull the switch and stall the machine. But neither does it have a moral right to operate inefficiently and without profit.

What is the determining factor, the ultimate key, to the well-being and progress of such a machine? Is it availability of raw materials, existence of markets, economy of operation? First and foremost it is the individual human being—the economic, social, political being. What he thinks and how he acts, as a customer or stockholder, but especially as an employee, determines the continued existence of industry in our country. Scientific research, fine engineering, precise manufacturing, and wasteless distribution will continue to be our stock in trade—they must be. But today they will not stand alone. The engineer in industry, who has played so large a part in making these things possible, must continue to apply himself to them. But his job does not stop there.

Truly, industry expects to perpetuate itself through the activity of the engineer, in the functional sense. It will continue to need his achievements, his orderly thinking, and his vision in the accomplishment of its everyday tasks. But it will need in even greater measure the application of these same talents to human problems which beset us today in so great a measure. In the gradual re-forming of corporate entities to meet the hard challenges of modern business life, with the tremendous complications of government regulation and participation, and of militant and often hostile labor activity, the burden has shifted more and more to the shoulders of management. Rather, we should say that it has shifted to the management ability that must be inherent in all of us, for management today is not the allotted task of a relatively few men at the top. It is the job of every division and section head, of every supervisor and foreman, of every man in the entire structure whose responsibilities include the direction of human effort, either in the direct line or at the so-called staff level, involving such things as employee, community, and public relations. Never before in business has human leadership been so all-important. And the man who can lead is the one who can make himself understood and believed.

SUMMARY OF EXPECTATIONS

There is a temptation to say to the young engineer, "Don't be *too* professional," but that is not wholly right, either, because the true bench-mark of the professional man is his understanding. It is wrong to think that we can overcome our industrial troubles by fighting them, by jamming through decisions which we may know to be correct, technically and economically speaking. By such conduct we will only leave bruises, and we will evoke no confidence. The human unit in industry is above all an individualist, and he must be treated as such.

These are some of the things that I believe industry expects from the engineer—achievement, orderly thinking, vision, and the ability to apply these great gifts to human, as well as technical, problems. If I could be permitted to make only one suggestion to the engineer as he faces a career in American industry, it would be this: don't be content to deliver just what is expected. Give industry more than it expects. You will then be rewarded by being given even more responsibility and more problems; these are the dynamics of true progress.

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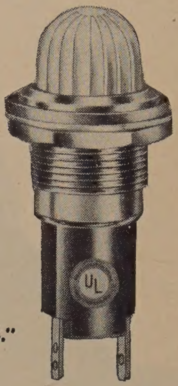

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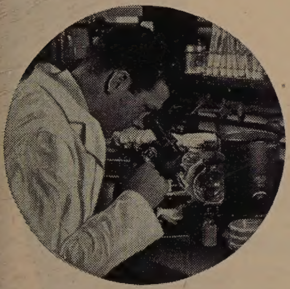

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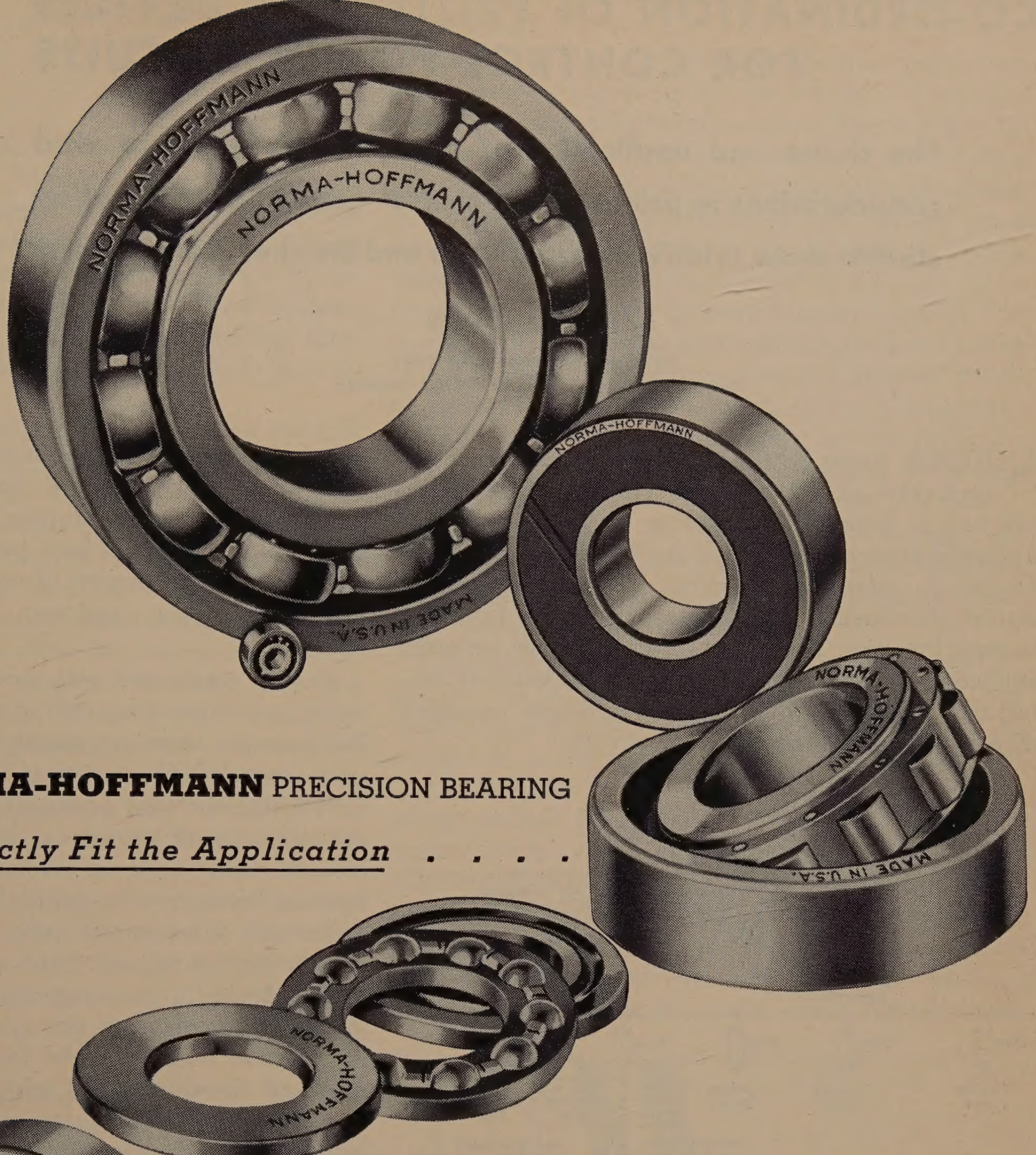

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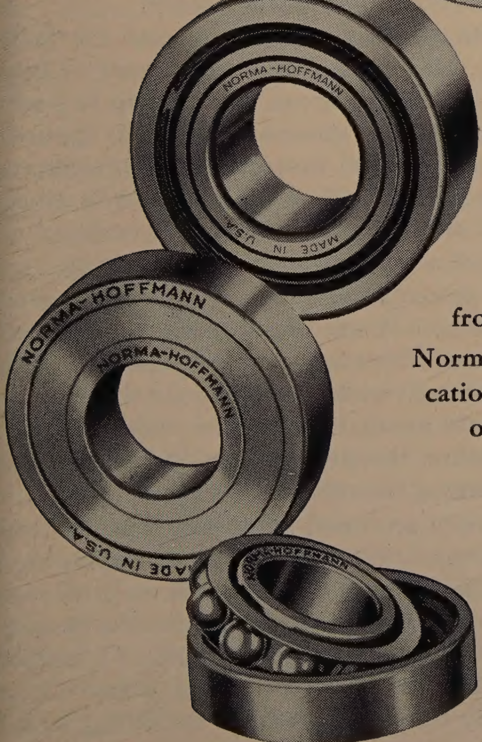

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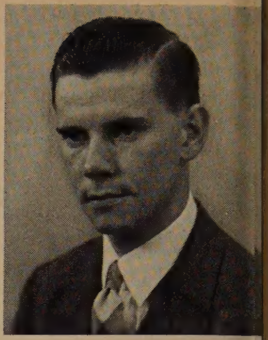
CO-ORDINATION OF PROTECTIVE DEVICES FOR CONTROL-POWER CIRCUITS

The choice and application of protective devices are vital considerations in protection of control circuits. Co-ordination studies show relative merits of fuse and breaker combinations



By JAMES R. PALMER
Switchgear Engineering Division
Philadelphia Works, General Electric Company

SHOULD fuses or thermal breakers be used for protection of control-power circuits? This article will help to answer that question by presenting, first a consideration of the general application of protective devices to control-power circuits of switchgear; and second, the results of a co-ördination study of fuses and thermal breakers. This study shows that fuses properly applied to control-power systems provide selective protection of circuits while thermal breakers equipped with instantaneous trips generally do not.

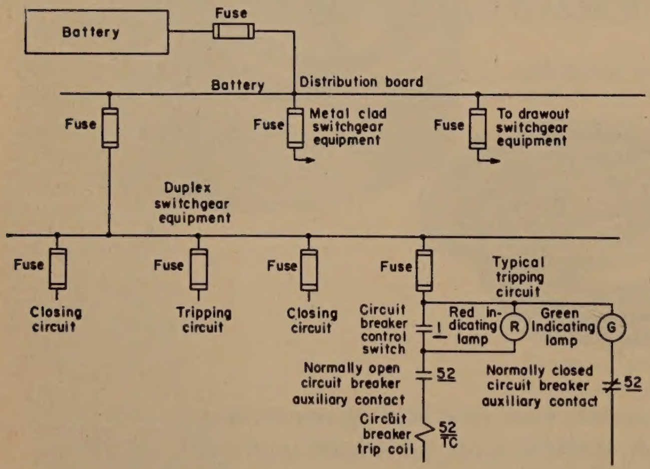

Battery
Fuse
Battery
Distribution board
Fuse
Fuse
Metal clad switchgear equipment
Fuse
To drawout switchgear equipment
Duplex switchgear equipment
Fuse
Fuse
Fuse
Fuse
Typical tripping circuit
Closing circuit
Tripping circuit
Closing circuit
Circuit breaker control switch
1
Red indicating lamp
R
Green Indicating lamp
G
Normally open circuit breaker auxiliary contact
52
Normally closed circuit breaker auxiliary contact
52
Circbit breaker trip coil
52/TC

Fig. 1. Single-line diagram of a typical control-power circuit, illustrating its resemblance to a radial distribution system

Control-power circuits used for fault tripping of circuit breakers must be reliable. It follows that faulted circuits should be isolated from other circuits; and protective devices, correctly applied, will provide that isolation. In other words, these protective devices *must be selective*. The lack of selectivity on control-power circuits used for other than tripping, while not so serious as on tripping circuits, is still objectionable because of unnecessary interference with control operations on unfaulted circuits.

APPLICATION OF PROTECTIVE DEVICES

A control-power system is simply a radial distribution system as shown in FIG. 1. In the typical installation, the control-power battery supplies a distribution board through the battery-protective device, and here branch-protective devices supply each individual switchgear equipment, duplex, metal-clad unit, drawout unit, and so on. These protective devices are located as near the source of power as possible to give protection to the maximum length of control conductor.

At each equipment unit, protective devices are provided for the operating coils of each main-circuit device. For example, there are usually separate protective devices for each of the closing and tripping circuits of each electrically operated power-circuit breaker. Whenever common control equipment is used for a number of breaker units, such as control for the starting and running breakers of a reduced-voltage motor-starting equipment, the common control is provided with common protective devices. Fault currents at the last protective device in the series may be almost as great as in any other place in the system, since the battery distribution board may be located in one switchgear unit and the closing and tripping fuses for that unit may be mounted also in the same unit with very little load resistance between it and the battery.

In general, protective devices are chosen for fault protection only. However, it is advantageous to fuse closing coils so that, if the circuit breaker fails to close, the fuse will blow in 5 to 10 sec after power is applied, thus giving some overload protection and preventing serious damage to the coil. A 10-amp fuse is small enough for fault protection, so usually fuses rated below this value are not used for control-power circuits.

A separately protected tripping circuit or bus is used in every case for each circuit breaker, or for each group of circuit breakers comprising a single equipment which is tripped by protective relays. This limits the number of circuits directly associated with the protective tripping of the breaker, thereby reducing the exposure to faults and increasing the reliability.

Tripping circuits are fused at no less than 35 amp and at not less than two times the total tripping current drawn while tripping off a unit. Since a 35-amp fuse is the smallest fuse that will fit into the 60-amp fuse clip, its use precludes the substitution of a smaller fuse that may be inadequate. The 60-amp fuse clip is also more sturdy than a smaller clip. Indicating lamps

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are placed on tripping fuses wherever possible to give assurance that tripping power is present before the circuit is closed.

CO-ORDINATION STUDY

What device should be used for protection of control power circuits: thermal breakers or cartridge fuses? Since the primary requirement is selectivity, the answer to this question is provided by a co-ordination study of four possible combinations of the two types of devices: fuse protecting fuse; breaker protecting breaker; fuse protecting breaker; and breaker protecting fuse. The study includes fuses and breakers rated from 10 amp to 400 amp.

The standard thermal element in the smaller thermal breakers is self-protecting; that is, it can withstand instantaneous short-circuit current up to the interrupting capacity of the breaker. But above a certain rating, thermal breaker manufacturers find it economically desirable to use an instantaneous magnetic trip rather than to build a super thermal element to protect itself. Standard breakers above 50 amp rating have an instantaneous magnetic trip. It is these standard breakers and the common 250-volt NEC cartridge fuses that have been considered in the co-ordination study. It is desirable to use "off-the-shelf" devices. A specialized stock of infrequently used devices is obviously to be avoided both from manufacturing and replacement viewpoints.

Control batteries for switchgear seldom exceed 400-amp one-minute rating, with 8 to 10 times this value obtainable as maximum short-circuit current. Since this is well within the interrupting capacity of the protective devices here considered, the problem is simply one of selectivity.

To obtain selectivity between two thermal breakers in series, it is necessary for the maximum interrupting time of the breaker nearer the load to be less than the minimum tripping time for the breaker nearer the source. To obtain selectivity between two fuses in series, it is necessary for the maximum total clearing time for the fuse nearer the load to be less than the possible-damage-limit time for the fuse nearer the source. Information needed for the co-ordination study is, then, maximum interrupting time and minimum tripping time for thermal breakers, and maximum total clearing time and possible-damage-limit time for fuses. Fuse manufacturers usually supply an average-melting-time vs current characteristic for their fuses. This study assumes, for sake of conservatism, that the time-current characteristics of all fuses of the same rating will fall in a band whose width in terms of current is plus or minus 10 percent of the average characteristic. Arcing time is added to the maximum melting time to obtain a maximum total clearing time, the upper co-ordination limit for the fuse in question. The minimum co-ordination limit is taken as 75 percent in current of the shortest melting time. The 75 percent margin has been used to insure no damage to the element of a "source" fuse when a "load" fuse blows or a "load" thermal breaker trips, and therefore it is called the "possible damage limit."

Thermal breaker manufacturers publish time-current characteristics consisting of two curves, a maximum- and a minimum-tripping-time curve. This band width defines the extreme limits of variations in characteristics of individual breakers due to operating and manufacturing tolerances. Interrupting time of 0.05 sec is assumed and this is added to the maximum tripping time to obtain a maximum-interrupting-time curve. On all breakers having an instantaneous magnetic trip, operation is assumed as taking place at 8 times rating. While instantaneous trips are usually operated from 8 to 12 times rating, the minimum factor is used. Since selectivity is absolutely necessary in the protective device, data used to establish the tripping point must be such as to give results that are on the *safe* side.

It is believed that the band widths for breakers and fuses are wide enough to eliminate the necessity of additional "safety, operating, or manufacturing-tolerance factors" in the co-ordination.

Characteristics of the devices to be co-ordinated are plotted on standard Joint EEI-NEMA Fuse Committee log-log paper. The curves for each device are plotted on a single sheet. For convenient comparison, curve sheets for the two devices whose co-ordination is being checked are placed on top of each other on a lighted tracing table which effectively places the two characteristics on the same set of co-ordinates.

FIG. 2 shows the co-ordination of 60-amp and 30-amp NEC cartridge fuses. The load device is the device closest to the load and the source device is closest to the source. The point where the maximum-

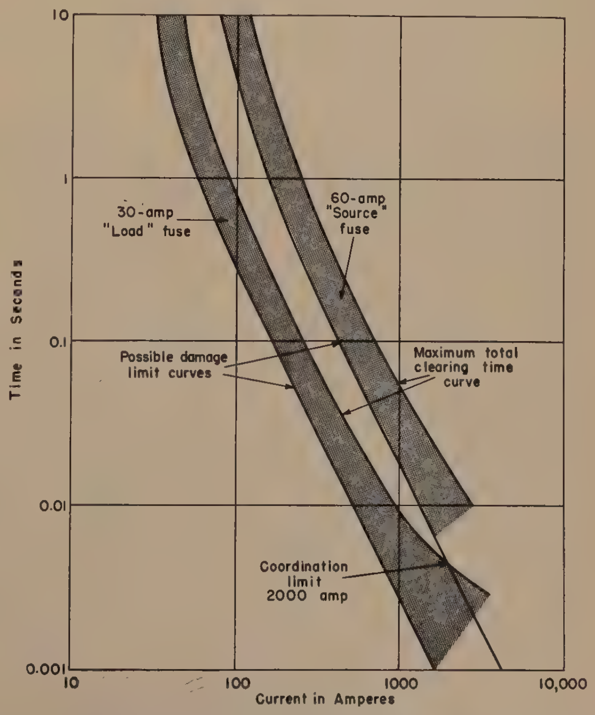
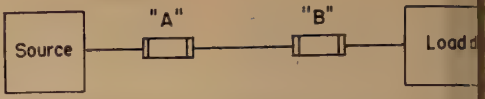


Fig. 2. Co-ordination of protective devices (here, fuse with fuse) is indicated by the superposition of plots of their operating characteristics. The co-ordination limit in terms of maximum short-circuit current (given in the accompanying tables) is given by the intersection of the inner boundaries of the devices' operating regions

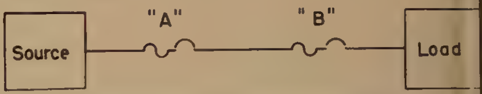
TABLE I: CO-ORDINATION STUDY OF 250-VOLT NEC FUSES



Rating in Amperes of Load Fuse "B"		Rating in Amperes of Source Fuse "A"									
		20	30	45	60	80	100	150	200	300	4
		Maximum Short-circuit Amperes to Which Fuse "A" Will Be Protected									
	10	600	1300	3000	4500	6000	8000	10,000	10,000	10,000	10,00
	15	...	600	2400	3500	4500	6000	10,000	10,000	10,000	10,00
	20	...	....	1800	3000	4000	5000	9,000	10,000	10,000	10,00
	30	...	....	....	2000	3000	4000	8,000	10,000	10,000	10,0
	45	...	....	....	....	800	2000	4,000	10,000	10,000	10,00
	60	...	....	....	....	....	150	3,000	10,000	10,000	10,00
	80	...	....	....	....	....	....	1,700	9,000	10,000	10,00
	100	...	....	....	....	....	....	....	8,000	10,000	10,00
	150	...	....	....	....	....	....	....	....	9,000	10,0
	200	...	....	....	....	....	....	....	....	....	10,00
	300	...	....	....	....	....	....	....	....	....	..

NOTE: 10,000 amp is the upper limit of short-circuit current of this study.

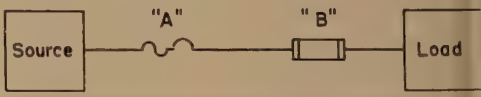
TABLE II: CO-ORDINATION STUDY OF THERMAL CIRCUIT BREAKERS



Rating in Amperes of Load Breaker "B"		Rating in Amperes of Source Breaker "A"								
		25	35	50	70	100	150	200	300	4
		Maximum Short-circuit Amperes to Which Breaker "A" Will Be Protected								
	15	450	1100	1900	560*	800*	1200*	1600*	2400*	3200
	20	...	1000	1800	560*	800*	1200*	1600*	2400*	3200
	25	...	700	1600	560*	800*	1200*	1600*	2400*	3200
	35	...	....	450	170	350	1200*	1600*	2400*	3200
	50	...	....	....	130	240	1200*	1600*	2400*	3200
	70	...	....	....	....	400	1200*	1600*	2400*	3200
	100	...	....	....	....	....	1200*	1600*	2400*	3200
	150	...	....	....	....	....	....	600	850	2600
	200	...	....	....	....	....	....	....	560	1500
	300	...	....	....	....	....	....	....	....	3200
	400	...	....	....	....	....	....	....	....	...

*These values determined by magnetic trip of device "A" taken as eight times rating.

TABLE III: CO-ORDINATION STUDY OF A LOAD FUSE AND A SOURCE THERMAL BREAKER



Rating in Amperes of Load Fuse "B"		Rating in Amperes of Source Breaker "A"								
		20	35	50	70	100	150	200	300	40
		Maximum Short-circuit Amperes to Which Breaker "A" Will Be Protected								
	10	10,000	10,000	10,000	560*	800*	1200*	1600*	2400*	3200
	20	....	6,000	10,000	560*	800*	1200*	1600*	2400*	3200
	30	....	....	10,000	560*	800*	1200*	1600*	2400*	3200
	45	....	....	....	560*	800*	1200*	1600*	2400*	3200
	60	....	....	....	....	800*	1200*	1600*	2400*	3200
	80	....	....	....	....	....	1200*	1600*	2400*	3200
	100	....	....	....	....	....	1200*	1600*	2400*	3200
	150	....	....	....	....	....	.....	1600*	2400*	3200
	200	....	....	....	....	....	.....	.....	2400*	3200
	300	....	....	....	....	....	.....	.....	.....	3200
	400	....	....	....	....	....	.....	.....	.....	....

*These values determined by magnetic trip of "A" device taken as eight times rating.
NOTE: 10,000 amp is the upper limit of short-circuit current of this study.

interrupting-time curve of the load fuse intersects the possible-damage-limit curve of the source fuse is the co-ordination limit—in this case, 2000 amp. If the fault current exceeds this value, it is no longer certain that the load fuse will interrupt the circuit before the source fuse is damaged or even melts and interrupts the fault that should have been removed by the load fuse alone.

Table I shows the results of the co-ordination with fuses used for both devices. The ampere ratings of the various source fuses "A" are listed across the top, and the ratings of the load fuses "B" down the side. To locate co-ordination results for the two devices, simply find the intersection of the column headed by the rating of the source fuse and the line designated by the load fuse rating. The number found at this intersection is the co-ordination limit and is the maximum value of fault current for which the two devices will certainly co-ordinate. If a blank space appears at the intersection, no co-ordination is possible. With a 60-amp fuse at the source and 30-amp fuse at the load, the co-ordination limit is 2000 amp as derived from the curves shown in Fig. 2. Whether this value of short-circuit current is sufficient for co-ordination in a specific application depends on the size and short-circuit characteristic of the control battery used and the conductor resistance to the load fuse; in other words, it depends on the short-circuit current available at the load device. In most cases, when the rating of the load fuse is 30 amp or above, the source fuse that co-ordinates with a given load fuse will be twice the rating of the load fuse. The upper limit of current in this co-ordination study is 10,000 amp since this is the value of current at which the Underwriters' Laboratories test cartridge fuses. Batteries seldom produce short-circuit currents in excess of this value.

Fig. 3 shows the co-ordination of a 15-amp thermal breaker with a 150-amp breaker. The instantaneous trip on the source breaker limits the co-ordination to 1200 amp, or 8 times the rating of that breaker. This illustrates the difficulty encountered in co-ordinating thermal breakers; the instantaneous trip limits the co-ordination.

Table II shows the results of the co-ordination of breakers as both the load and the source devices. The breakers above 50-amp rating have instantaneous trips, hence it is impossible to insure selective tripping of these breakers until the rating becomes so high that the value of the instantaneous trip is above the expected short-circuit current at the load device. The figures marked with an asterisk in the tables are co-ordinations limited by the instantaneous trip. For example, assume a control battery which will produce maximum short-circuit current of 2400 amp. It is further assumed that a 15-amp breaker would be suitable for the closing circuit and another for the tripping circuit. For the source protective device, a 50-amp breaker might be used if it is assumed that short-circuit current at the load breaker will be reduced by circuit resistance to 1900 amp, the limit for co-ordinating a 15-amp breaker with a 50-amp breaker. If, on the other hand, the short-circuit current at the load breaker were not reduced by circuit resistance below 1900 amp, a 300-amp source breaker with an instantaneous trip would be required to insure selectivity. This breaker would be too large to afford any protection to the battery.

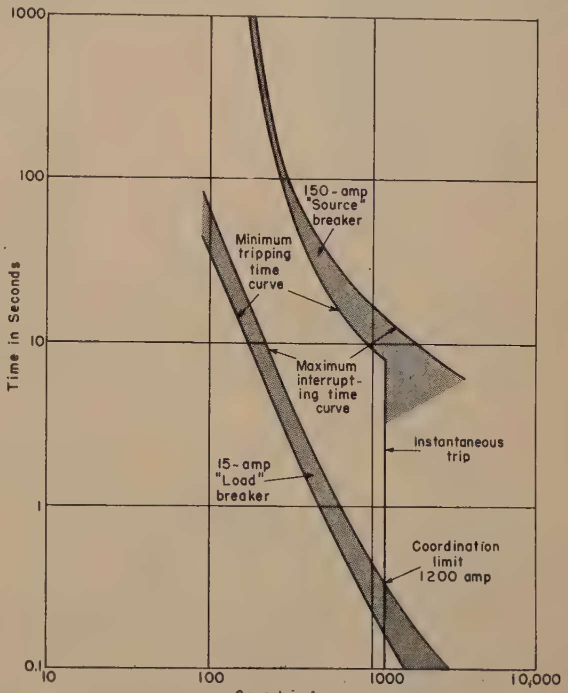


Fig. 3. Co-ordination of breaker with breaker is limited by the instantaneous-trip setting, sometimes with consequent difficulty in obtaining selectivity

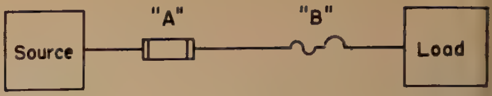
Table III shows that co-ordination results of a main circuit breaker "A" in series with branch circuit fuse "B" are very good where the instantaneous magnetic trip is not present (up to and including 50-amp breaker). Otherwise, the co-ordination is limited by the trip and it is not until the trip becomes higher than the expected short-circuit current that the co-ordination is possible. A 30-amp fuse usually co-ordinates with a 50-amp thermal breaker but a third device in series would have to be another breaker. This leads to the difficulty experienced in Table II.

Table IV shows that the "source" fuse current rating must be objectionably high to give selectivity with a "load" thermal breaker. In fact, if a 15-amp thermal breaker were used at the load, a 200-amp fuse would be required to give selectivity if the source were a 200-amp one-minute rating battery; while, if both devices were fuses, a 15-amp load fuse would require only a 45-amp source fuse for selectivity under the same conditions.

ADVANTAGES AND RESULTS

There are advantages of thermal breakers over fuses. Thermal breakers lend themselves readily to dead-front construction, combining the control-power switch and the circuit protection in one device, although a switch

TABLE IV: CO-ORDINATION STUDY OF A LOAD THERMAL BREAKER AND A SOURCE FUSE



Rating in Amperes of Load Breaker "B"	Rating in Amperes of Source Fuse "A"							
	45	60	80	100	150	200	300	400
	Maximum Short-circuit Amperes to Which Fuse "A" Will Be Protected							
15	50	110	230	500	1000	2400	3600	6600
25	..	60	90	160	560	2200	3500	6600
35	..	...	70	110	200	1900	3500	6600
50	..	...	...	100	160	900	2600	6600
70	..	...	...	...	....	2300	3500	6600
100	..	...	...	...	....	....	3500	6600
150	..	...	...	...	....	....	330	560
200	..	...	...	...	....	....	....	450
300	..	...	...	...	....	....	....	....

and a dead-front fuse mounting can be used with almost equal simplicity. With a thermal breaker, one never has to worry about looking for a fuse in the dark, or about using the wrong size, which nullifies all the work ever done to co-ordinate the fuses.

In this application an important advantage of fuses over thermal breakers is that fuses at most currents give faster circuit protection than a thermal breaker of the same current rating.

Summarizing the four co-ordinations:

(1). *Two fuses in series.* Fuses provide selectivity for all ratings with reasonable steps between the ratings of co-ordinated fuses

(2). *Two breakers in series.* Two breakers will co-ordinate in reasonable steps if the source breaker is without instantaneous trip (50 amp or less)

(3). *A load fuse and a source breaker.* These two devices co-ordinate nicely as long as the thermal breaker does not have an instantaneous trip. However, if a third device is required in series, it will probably have to be a thermal breaker with an instantaneous trip and its size for selectivity will be excessive.

(4). *A load breaker and a source fuse.* This combination is practically without value for selectivity.

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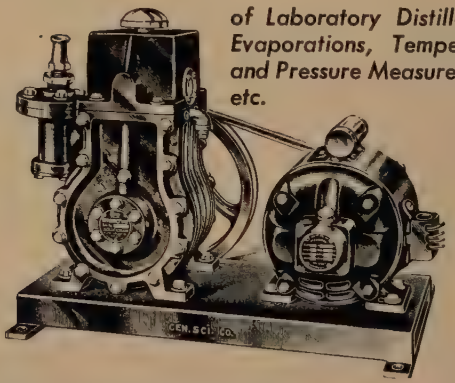

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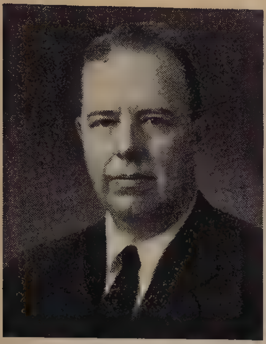
NEW LABORATORY FACILITIES TO IMPROVE ENGINEERING EFFORT



John A. Miller

> **"There are fields to conquer which far outrank those of our pioneering past."**
>
> *From address by Charles E. Wilson, President General Electric Company, at Clarkson College Anniversary Convocation—October 8, 1945*

By
JOHN A. MILLER
General Engineering and Consulting Laboratory
and
JOHN HORN
Staff Assistant, Engineering Policy Division
General Electric Company

John Horn

LABORATORY facilities are a sound investment. They pay for themselves many times over in acquired knowledge, improved engineering and manufacturing effort, in new and better products, and in whole new industries. That has always been the philosophy of General Electric and of President Charles E. Wilson, under whose leadership the Company's laboratory facilities have been greatly expanded.

Mr. Wilson's and the Company's continuing faith in this philosophy has been demonstrated particularly by the expansion of laboratory facilities that has taken place since the end of the war. During this period completely new laboratories have been constructed at Schenectady (N. Y.), Lynn River Works and West Lynn Works (Mass.), Syracuse (N. Y.), Pittsfield (Mass.), and Waterford (N. Y.). At the same time notable enlargements and improvements of laboratory facilities have been made at dozens of other locations. Already some $50,000,000 has been spent on these projects and substantial additional expenditures are planned.

The broad scope of activities for which new laboratory facilities have been provided in this postwar period covers such diverse fields as aeronautics, atomic power, and electronics, as well as the basic sciences and the traditional fields of electrical engineering measurement, lighting, and materials testing.

So, today, General Electric's group of industrial laboratories stands without parallel anywhere in the world. The original one-room laboratory established at West Lynn in 1884 for the purpose of standardizing electrical measurements has grown to a group of widely spread laboratories for many purposes. Laboratory personnel has increased from one man who knew instruments into about 5000 scientists, engineers, and assistants.

SPECIALIZED FACILITIES IN ELECTRONICS LABORATORY

When World War II ended, General Electric found itself with a large electronics business carried on in 22 different plants with no central headquarters plant. The development of this situation had been foreseen some years before and planning had been started on a brand new plant where the various scattered divisions of the Electronics Department could be housed at one location, just outside of Syracuse. There construction of Electronics Park was started in September 1945 to provide facilities for research, engineering, and production on a scale never seen before in the electronics business. Nine major buildings have been constructed on this tract.

The new Electronics Laboratory at Electronics Park in Syracuse provides ideas for electronics developments. Shown here is a developmental receiver undergoing evaluation tests in that laboratory

The over-all research and development unit of this group is the Electronics Laboratory, a two-story steel-frame structure. The function of this laboratory lies midway between the pure research work carried on in the G.E. Research Laboratory at Schenectady and the operating divisions' engineering laboratories concerned with development specifically for production. Its scope is to develop ideas from the pure research stage to the advanced development stage, in all the fields of the several divisions of the Electronics Department.

As each of the operating divisions is provided with basic laboratory equipment, the facilities of the main

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This article is so paged that, without mutilating other articles, it can be readily removed for filing as a group of full-size consecutive pages.—EDITOR

laboratory are of a more specialized nature. Among them are a chemical laboratory for testing materials, a plating laboratory, painting laboratory, welding laboratory, metallurgical laboratory, photographic darkrooms, and a model shop staffed with skilled mechanics and wiremen.

The responsibility of the development engineers of the main laboratory is to think first of the future and to take calculated risks in reducing research to practice as fast as possible, for the advancement of the art. It is not expected that everything tried will work, nor is it expected that everything which works will get into production. All that is expected of the laboratory is a continued output of ideas, ready for the next stage of development by the operating divisions.

RESEARCH LABORATORY FOR JET ENGINES

Development and production of turbosuperchargers and turbojet engines were among General Electric's outstanding contributions to the war effort. In the short period since the first jet plane flew in this country, the turbojet power plant has risen to the status of almost universal acceptance for fast military aircraft, and the Company has greatly expanded its facilities at Lynn River Works for the development, testing, and production of aircraft jet engines. Included in this program has been the construction of a new laboratory for testing jet-engine components.

Much of the early progress on jet engines resulted from effective application of established design practice and procedures. Continued advances, however, have required a more thorough and complete understanding of all the factors affecting the performance of the major components.

Shortly after V-J Day, in 1945, engineering studies were begun to define what specific research and development testing facilities would be required by the Company to maintain an aggressive program for continued development of aircraft gas-turbine power plants. By March 1946, a proposal had been formulated and preliminary engineering work was begun.

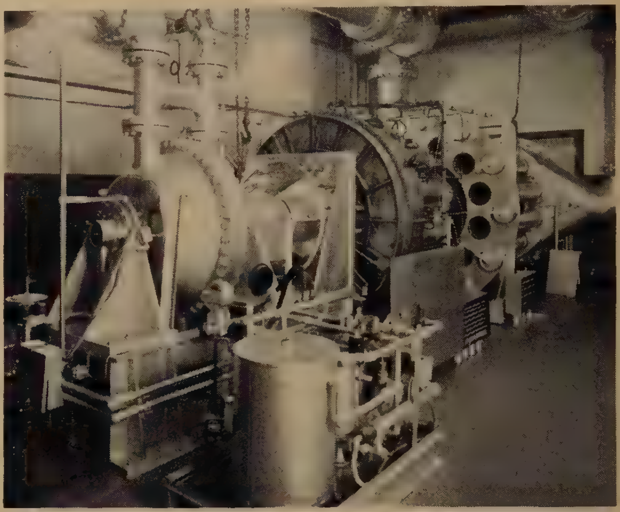
Because the development of a turbojet engine can be most effectively accomplished after the performance of its components has been established, it was decided to design facilities for testing the individual components. For that reason, test facilities have been provided for the following:

(1). Full-scale compressor components, which provide for testing under all expected operating conditions of altitude, temperature, and pressure.

(2). Full-scale turbines, wherein the thermodynamic conditions can be accurately controlled and measured, together with provision for the absorption and measurement of the shaft power developed.

(3). Full-scale combustion assemblies, wherein tests can be conducted over the range of pressures from atmospheric to the maximum obtainable from the test compressor.

(4). Single and multiple compressor stages to provide a facility for evaluating and screening the performance, under variable temperature and pressure conditions, of scale models of advanced design. These models are built by tool-room methods to obtain performance data on new designs rapidly and economically, as is needed in the selection of designs for full-scale machines.



One facility for testing jet-engine components at the Lynn River Works is this full-scale turbine test stand. Housed in a single-story building, it and numerous other component testing equipments contribute to aircraft-gas turbine development

The building constructed to house the component-testing facilities, development accessory and control-test equipment, and offices for the test engineering, planning, and drafting organization is basically a single-story structure. It does include, however, a basement area around the compressor test and driving turbine, and there the turbine auxiliaries, heat exchanger, pumps, etc., are installed. The building also houses the central control room which serves the compressor, turbine, and combustion tests.

In addition to the component-testing equipment, many other research and development tools are essential to continued progress in the design of aircraft gas turbines. Thus equipment and facilities have been developed and used to satisfy special testing requirements such as:

(1). Operation of accessories and controls under all expected operating pressures and temperatures from −67 F to 160 F.

(2). Cyclic endurance testing of complete engine-control systems, also at high or low temperatures.

(3). Cold-starting tests, wherein the entire engine can be cooled to temperatures as low as −67 F, maintained at these temperatures for any desired period, after which a start can be attempted and engine operation observed up to idling speed.

(4). Overspeed testing of compressor rotors and turbine wheels, providing for operation either up to and including the bursting speed for development testing of new designs or as a regular manufacturing quality-control procedure.

While major component jet parts, such as the turbine ind compressor, can be tested in the new laboratory inder actual and varying flight conditions, the full-size ngine is tested under actual altitude conditions aboard he B-29 flying laboratory operated by the Company t its Flight Test Center near Schenectady.

LIGHT-TEST FACILITIES

General Electric's success in meeting military aviaion requirements has been due in no small degree to he establishment of its flight-test program. Just two nonths after World War II began, the Company naugurated the use of airplanes converted into flight-est laboratories. Headquarters for the flight-test proram was first located at La Guardia Field (N. Y.), hen at Brownsville (Texas). Shortly before the end of he war it was moved to Schenectady.

Construction of a suitable building was started at he Schenectady County Airport in September 1945, ind was completed in June 1946. Built of poured conrete, the building contains a hangar 160 ft wide, 180 t deep, and 45 ft high in the center. Two floors of aboratories, workshops, and offices extend down one ide. In front is a control tower which houses radio quipment of various types. These facilities are operated by the Flight Test Division of the Company's General Engineering and Consulting Laboratory.

Although many of the projects involve equipment being developed under military contract, most of them will be beneficial to commercial and private aviation is well. Among the flight-test projects of importance o nonmilitary aviation are those which would improve he following: automatic pilots; pressurized passenger abins; radio performance; propeller synchronization; power boost for control surfaces; control devices for ngines, landing gear, cowl and wing flaps; deicing quipment; and others.

New facilities for the development and testing of power plants for proposed jet-propelled helicopters vere established adjacent to the hangar at the Flight Test Center, under the auspices of the General Engieering and Consulting Laboratory's Thermal Power Systems Division.

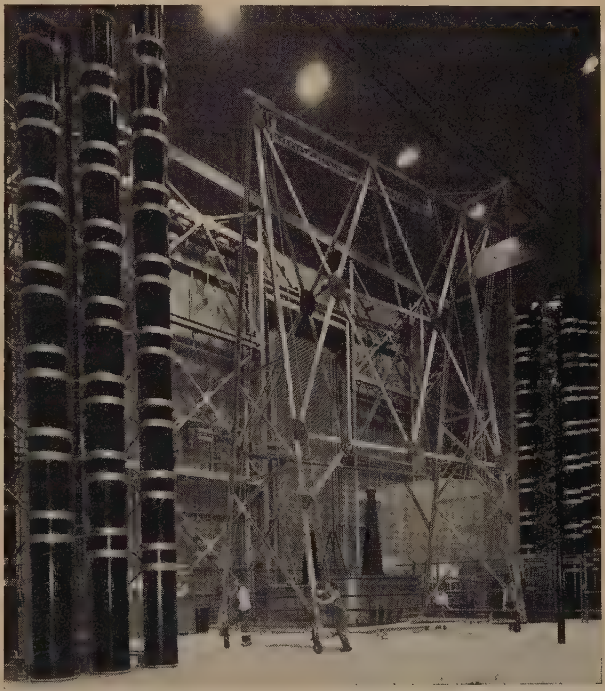
Those facilities include an outdoor bowl-shaped pit, 50 ft in diameter and 13 ft deep, with propelling nechanism for the testing of jet units located at the ips of the whirling helicopter blade; two all-steel strucures, each 40 by 80 ft, for laboratory and workshop ctivities; and control and instrument facilities for the propelling mechanism. To safeguard the engineers luring the testing of the rapidly whirling helicopter plade, a special observation room, adjoining the pit, las been erected with concrete walls three feet thick.

IGH-VOLTAGE ENGINEERING LABORATORY

When the famous Charles P. Steinmetz made the first erious attempt to duplicate the destructive effects of natural lightning in 1921, he used a specially built 120,000-volt lightning generator in the General Engineering Laboratory at Schenectady. Several years later this research was transferred to Pittsfield, where high-voltage impulses had been used since 1914 in connection with lightning-arrester design. Today in the new High-voltage Engineering Laboratory there, bolts with more than 100 times the voltage can be generated and studied.

The new High-voltage Engineering Laboratory, with its ultra-modern equipment, supplants the high-voltage laboratory facilities built there in 1914. It will make possible the extension of research in all kinds of high-voltage phenomena and also provide unexcelled means for design and performance studies of larger equipment, including transformers, lightning arresters, capacitors, and bushings.

Built at a cost of more than $2,000,000, the new laboratory includes two adjoining buildings called the High Bay and the Low Bay, together with a large outdoor test area. The total available room space is 51,000 sq ft.



The new $2,000,000 High-voltage Engineering Laboratory at Pittsfield is making possible extended research in high-voltage phenomena. A view in the 85-ft-high High Bay test area with its two 7500-kv (peak) impulse generators is shown here

The high bay consists of a single windowless room 165 ft long, 95 ft wide, and 85 ft high. The low bay is a three-story structure, 215 ft long, 84 ft wide, and 55 ft high. On the first and second floors of the low-bay building are offices, a lecture hall, photographic darkrooms, electrical and mechanical workshops, storage rooms, and an air-conditioned test room where the humidity can be controlled over a wide range and the temperature from 0 F to 100 F. The entire third floor is used for lightning-arrester development.

The laboratory has a total of ten testing areas, including the outdoor area. In these areas are located eleven high-voltage testing transformers, ranging in size from 100 kv to 350 kv (rms). To obtain higher voltages several of the transformers are connected in cascade groups producing up to 1050 kv, with a future provision to obtain 1750 kv. Six impulse generators are available, ranging from 200 kv to two having a 7500-kv peak. In addition there is a surge-current generator capable of producing 260,000 amp.

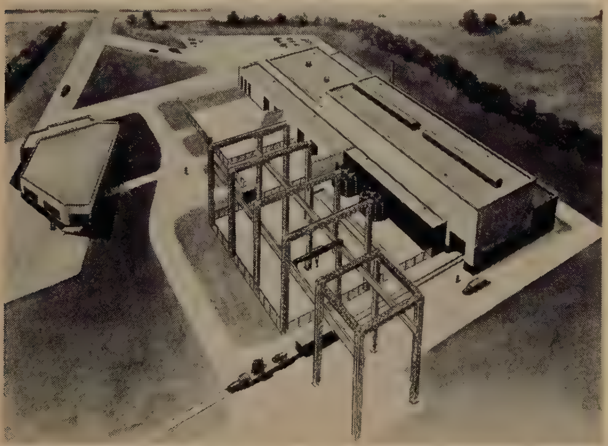
The two 7500-kv generators can be connected in parallel to obtain a 66,000-amp discharge, a current equal to that of a very heavy natural lightning stroke. When connected in series, these two impulse generators can spark over a gap of 55 ft. Seven cathode-ray oscillographs of the hot-cathode type are used to record the transients.

For tests on gases, a large high-pressure tank is available, and for investigations on liquid and solid insulations, there are a number of large tanks, as well as numerous smaller portable tanks.

With the completion of these extensive new facilities Pittsfield has become the undisputed "man-made lightning" center of the world.*

HIGH-POWER SWITCHGEAR TESTING

Scheduled to be in operation early in 1951, a new high-power switchgear testing station is being constructed near the Switchgear Divisions plant in Philadelphia (Pa.). This will completely replace the test facilities now located in Schenectady. Two testing generators are to be used for direct connection to the test cells and through step-up transformers to the high-voltage yard. These two generators may be paralleled, or they may be operated independently on two separate series of tests at the same time.



Proposed facilities of the High-power Switchgear Testing Station at Philadelphia, for the development of circuit breakers and switchgear components, scheduled to be in operation in 1951. The station's high-voltage yard is shown in the foreground

Other facilities such as high-current testing, load-life testing, etc., are being included in the design of this station. While the output of this new testing station will be considerably larger than the present one, it will still be necessary to continue to some extent th present two-part testing method and to continue t use synthetic testing technique as well as field tes ing of the higher rated equipment as has been don in the past.

This new and modern testing station will be an ex tremely useful tool to the switchgear engineers in fu thering their design and development work.

OUTDOOR LIGHTING CENTER

As part of an extensive program for the manufactu of outdoor lighting equipment, new and enlarged facili ties have been provided for the Illuminating Labora tory at West Lynn. This laboratory, together with demonstration room and associated offices, occupie about 22,000 sq ft of floor space.

A light-distribution measurement being made on a modern street-lightin unit at the Illuminating Laboratory, West Lynn. This laboratory is designe for evaluation and development of all types of outdoor lighting equipmen and makes use of the latest techniques in measurements

The principal function of the laboratory is to dete mine the light output and light distribution characte istics of the street lights, flood lights, airport lightin units, traffic signals, reflectors, and allied equipmen manufactured by the Lighting Division. About half c the space devoted to laboratory testing is occupied b the test range, a room 130 ft long, equipped with goniometer to position at any desired angle the uni being tested, and a movable integrating hemispher into which the light beam is admitted through an ad justable opening.

All the laboratory rooms are finished in matte blac to prevent extraneous light reflection from walls an ceilings. An additional precaution on the test rang consists of curtains which can be lowered to creat what is virtually a tunnel between the light source be ing measured and the measuring instrument, thus pre venting any stray light from entering the main beam

For determining the pattern of light distributio use is made of a distribution photometer designed an built by the engineers of the laboratory. Since color i becoming of increasing importance as light sources of different spectral composition are introduced, the laboratory equipment includes a recording spectrophotometer.

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*For a detailed description of this laboratory see the article "New High-voltage Engineering Laboratory," by J. H. Hagenguth, GENERAL ELECTRIC REVIEW, Sept. 1949, page 9.—Authors.

Owing to the wide range of applications for outdoor lighting, it is frequently necessary to solve problems far afield from purely electrical and lighting matters in preparing recommended layouts. For this purpose, men trained in mechanical design and art are included in the laboratory staff.

METER AND INSTRUMENT FACILITIES

An ultra-modern five-story brick-and-steel building, which will house a completely equipped electrical measurements laboratory, is being erected at West Lynn by General Electric's Meter and Instrument Divisions. Official ground-breaking ceremonies were held December 29, 1948. The building is scheduled to be completed in 1950.

This modern brick-and-steel building will house a completely equipped measurements laboratory for the Meter and Instrument Divisions at West Lynn. It is scheduled for completion in 1950 and will provide 142,000 sq ft of floor area

The structure will be H-shaped and will have 142,000 sq ft of floor area. In addition to providing space for the most modern equipment for developing new products, materials, and processes, it will house a 500-capacity auditorium and also offices and rooms for exhibits and other purposes.

LOCOMOTIVE AND CAR EQUIPMENT FACILITIES

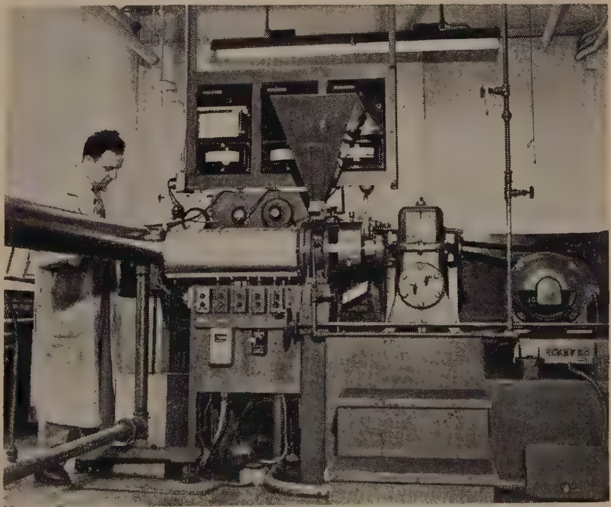
Early in 1949 the Works Laboratory at Erie (Pa.) was divided into two separate laboratories, one for the Refrigerator Division of the Appliance and Merchandise Department, and the other for the Locomotive and Car Equipment Divisions of the Apparatus Department. With this separation, the construction of completely new facilities for the Locomotive and Car Equipment Laboratory was started.

It was decided that this project should be carried out in three steps. Two of these steps have been taken so that additional floor space and new facilities are now available for the Insulation, Welding, Mechanical, and Electrical Sections. By about March 1950 it is expected that the third step will provide new quarters for the Metallurgical and Chemical Sections. The Locomotive and Car Equipment Divisions will then have a thoroughly modern laboratory to carry on applied research and development, testing, calibrating, and other technical services in the interest of furthering advances in equipment for public transportation.

A scene in the gage-calibration area in the Electrical Section of the new Locomotive and Car Equipment Laboratory at Erie

LABORATORY REARRANGEMENT AT BRIDGEPORT

With the creation of the Company's Construction Materials Department as a separate operating unit, laboratory facilities at Bridgeport (Conn.) were extensively reorganized. A separate Construction Materials Laboratory was set up and given responsibility for the testing and specification of materials and methods, for the development of new processes and manufacturing techniques, and for the development of new products. The new laboratory is divided into five sections: chemical; insulation; metallurgical; electrical; and mechanical. New metallurgical testing equipment has been added including a new metallograph for studying metal surfaces. Among other new equipment is an ionization-level tester for testing rubber-insulated power cable.



Some equipment of the thermoplastics development section in the newly organized Construction Materials Laboratory at Bridgeport.

APPLIED CHEMISTRY LABORATORIES

On the outskirts of the little town of Waterford is one of the most unusual plants in the world. It is the home of General Electric silicones. Here the Company's Chemical Department produces a family of synthetics in all of which silicon is the primary raw material. Among them are water repellents, resins, oils, greases, and synthetic rubber. The process of manufacture, which is almost entirely automatic, is carried out in an amazingly complex arrangement of pipes, tanks, stills, and reactors.

These silicones are already proving useful to industry in a wide variety of ways. To aid in finding new uses for existing silicone products, and to develop new and improved products in the silicone field, a well-equipped laboratory has been provided. It is housed in a new one-story brick building having a total of 9,000 sq ft of floor space. Its work is largely in the field of applied chemistry.

Six of twelve distillation columns used for small-scale silicone distillation at the Chemical Department's new silicone plant at Waterford

At Pittsfield, the Chemical Department has converted a brick structure, built during the war, into a chemical pilot-plant laboratory with 6,400 sq ft of floor space. The purpose of this laboratory is to provide space and facilities to progress new chemical products through the pilot-plant stage. Another laboratory containing 800 sq ft of floor space has been established in the same building adjacent to the pilot-plant laboratory. Here the objective is to study materials for the construction of process equipment in current use and for new processes.

A laboratory containing 2,000 sq ft of floor space has been established in the new Laminated Products Plant at Coshocton (Ohio). Its purpose is to provide facilities for developing new and improved laminated products and for application engineering activities in this field. At the Glyptal alkyd resin plant in Anaheim (Cal.) a control laboratory may serve as the starting point for expansion of laboratory activity.

AIR-CONDITIONING DEVELOPMENT LABORATORIES

Laboratory facilities of the Air Conditioning Department have been considerably improved and enlarged since the end of the war. At Bloomfield (N. J.) the laboratory floor space has been doubled, while the space for testing of air-conditioning equipment has been more than doubled. At Winter Street, Fort Wayne (Ind.) the existing space has been rearranged to allow testing of many more units, of larger sizes, and with better accuracy than ever before.

For testing central-plant air conditioners, self-contained air conditioners, evaporative condensers, etc., at Bloomfield, a large conditioned air supply has been provided by a unit capable of supplying a maximum of 900 tons of refrigeration. A maximum of 13,700 cfm of air with any desired combination of temperature and humidity from room temperature to −20 F can be accurately measured to determine the performance of the largest equipment being built there. A controlled-temperature water supply involving a possible 30 tons of refrigeration is also available for use for large condensing-unit tests.

A sound room for checking automatic heating equipment under actual operating conditions has been provided to supplement similar equipment already available for air-cooling equipment. The heating sound room will hold any reasonable ambient temperature while allowing the equipment to be operated at full rating. Combustion products are removed through an exhaust stack, and heat generated is discharged through air or water outlets, but all such outlets are baffled against stray noise to insure accurate measurements of the units under test.

Three new controlled-temperature rooms have been provided, one of which is a twin, allowing separate testing of two units when necessary. One of the other rooms is arranged for controlled conditions down to 0 F, while the third is primarily for high ambient temperature and humidity tests on packaged refrigeration devices.

A welding laboratory has been added which permits developing new techniques with various types of welding equipment. The Works Laboratory has been expanded and especially equipped for material and process-control testing and development.

In the modernization at Winter Street, the number of test rooms for checking performance of compressors and condensing units has been increased from four to seven, and the equipment has been rearranged for testing all sizes of units. Life-test racks have been built for handling the smallest fractional-horsepower units through the largest, either air- or water-cooled condensing units.

A new calorimeter capable of determining the pumping capacity of 125-hp compressors, twice as big as the present maximum size, has been constructed. This is considered to be among the most accurate equipments available for the purpose. Designed for economy in the use of water for testing, it recirculates the refrigerant in such a manner that only the heat of compression need be removed by the cooling water, yet the compressor can be loaded under any desired condition, with either F-12 or F-22.

A similar calorimeter designed especially for operation of low-temperature cooling tests, and a small special room for investigating the problems at temperatures down to −60 F are available when needed on special problems.

The sound measurement room has been outfitted with special equipment which allows determination of the essential quality of noise as well as its quantity to a degree never before attained. This is done by analyzing the noise in octaves and synchronizing its picture on a cathode-ray tube with the rotation of the compressor shaft.

NEW HOME FOR RESEARCH LABORATORY

Basic to the work of the product divisions of the Company and to the work of the various departmental laboratories, works laboratories, and the General Engineering and Consulting Laboratory, is the work in fundamental research done by the General Electric Research Laboratory. The established facilities for this work having been outgrown, plans were started in 1945 for a new Research Laboratory at The Knolls, near Schenectady. The first section has already been completed and has been occupied since November 1948. The second section, or north wing, is nearing completion. When finally completed the new laboratory will have a gross total of approximately 330,000 sq ft of floor space.

Situated on sloping ground, the completed unit has three stories above ground and two below ground on the front, while the rear has five full stories above ground. This unit contains laboratories devoted to electronics, high-frequency research, television, light production, physical studies, metallurgy, and crystallography. It also houses the administrative offices (temporarily) and the shops, the latter occupying a special two-story wing. When the new unit is completed, the administrative offices will be moved there, as will also the chemical group and other groups now housed at the main Schenectady Works.

Near by, the Radiation Laboratory is nearing completion. This is a special building built to house the 300-MEV nonferromagnetic synchrotron, now in an advanced stage of construction in the old laboratory. An addition to this building will be devoted to x-ray research. A short distance away on lower ground is the Low-temperature Laboratory—a building especially designed to house equipment for liquefying hydrogen and helium, and to provide facilities for carrying out a comprehensive program of research at very low temperatures. Also on the lower level is the Chemical Pilot Plant which will be used for reducing to practice, on an enlarged scale, processes that are developed in the Chemical Division of the Laboratory.

All of these facilities include the newest innovations in laboratory construction and are designed for maximum efficiency and flexibility.

Any room in the main building can readily be supplied with tap water, hot or cold, distilled water, city gas, hydrogen, oxygen, nitrogen, compressed air, rough vacuum, and steam at 125 lb per sq in. Electrical services available in any room are: 120/208-volt and 265/440-volt 3-phase 4-wire 60-cycle power; also 125/250-volt direct-current power.

The north wing of the new headquarters of the Research Laboratory at The Knolls in Schenectady is shown nearing completion. It will become an integral part of the main building, which is now in use and which lies just beyond the righthand edge of this photograph

An important feature of the laboratory is the convenient availability of shop services of all kinds, which are centrally located in a wing that projects from the east side of the building and includes the first and second stories.†

In addition, the Company has built for the Government the Knolls Atomic Power Laboratory on a tract of land adjacent to the Research Laboratory. It is now partially occupied and is expected to be fully operative soon. With the general objective of "power for peace" it will be operated for the Atomic Energy Commission by the General Electric Company under the supervision of the Research Laboratory. The principal aim of the atomic-power laboratory's work is the development of new types of nuclear reactors adaptable to industrial applications of nuclear energy.

With these unsurpassed facilities and an enlarged staff of specialists, the Research Laboratory will be well equipped to discharge effectively its prime responsibility—the task of pushing forward the frontiers of scientific knowledge.

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†For a detailed description of the Research Laboratory see the article "The Research Laboratory Builds a House," by Dr. H. H. Race, General Electric Review, Nov. 1948, page 11.—Authors.

APPLIANCE AND MERCHANDISE LABORATORY FACILITIES

The Appliance and Merchandise Department, which operates manufacturing plants in eleven cities, devotes some 93,000 sq ft to laboratory facilities, 75 percent of which are new since the war. The facilities of the Refrigeration Division in Erie (Pa.), which are a typical example, take in provisions for investigation of new materials, development of new processes, tests of incoming material, supervision of technical processes, tests of refrigerators and components in 20 test rooms, equipped with over 500 instruments, many of them specially designed by the Division. Ambient temperatures can be maintained from 0 F to 120 F, and any degree of humidity.

The facilities of the various appliance engineering units at Bridgeport and other plants provide for testing and development of washing machines, ironing machines, dryers, dishwashers, Disposalls, vacuum cleaners, automatic blankets, fans, toasters, mixers, flatirons, and other appliances. Special facilities include an airflow room for fans; a silent room for noise tests; a cold room; a heating laboratory (simulated dwelling to test electric heaters); and a complete laundry. Of great importance to clothes washer and dishwasher engineers is the continuous evaluation of detergents, and the investigation of the effect of water of different degrees of hardness on washing effectiveness.

A laboratory unique in character in the General Electric Company is the Food Research and Appliance Testing Laboratory at Bridgeport. Staffed entirely by women trained in biochemistry, bacteriology, food technology, and home economics, this laboratory is equipped to determine, for example, the effect on vitamin content, and deterioration, of food kept at different temperatures in refrigerators and freezers; the bacteria growth in food left out of a refrigerator, for example when placed in a range oven hours before cooking; and the effect on vitamins of various cooking processes. All such studies help guide the product designer, and help educate the housewife who uses the appliances. This Laboratory makes complete use-tests on appliances from the housewife's standpoint, endeavoring to discover what difficulties, if any, women might encounter in using the appliances. The laboratory thus represents the consumer to the engineering divisions. Wear-tests on various fabrics, in washing and ironing, are an important part of this laboratory's service.

OTHER EXPANSION PROJECTS

Throughout the Company, numerous other laboratory expansion projects have taken place since the end of the war. The Thomson Laboratory at Lynn River Works, for example, has recently established a special center for evaluating anti-friction bearings, for the study and appraisal of lubricants, and for evaluation of the compatibility of materials, all questions of much significance in the development of the Company's rotating apparatus. The Lamp Department has extended and improved its laboratory facilities to cover the changing needs of research and development. The Switchgear Divisions Laboratory at Philadelphia will shortly move into new and larger quarters. There, increasing emphasis will be placed on applied research.

Since the middle 1920's certain lines of motors and transformers have been produced at Oakland (Cal.). The facilities for this activity have been expanded in recent years and at the same time wire and cable as well as some control equipment have been added to the manufacturing program. Hand in hand with this development, the facilities and personnel for product advancement and applied research have been enlarged.

An electrometric titration to determine the vitamin C content of a food sample. This is one of the many unique functions performed in the Food Research and Appliance Testing Laboratory at Bridgeport

Numerous improvements have been made to the facilities of the Schenectady Works Laboratory. Of particular interest is the recent addition of the largest vacuum melting furnace in this country. It will be induction heated and will be able to melt lots of 300 lb of metal and to maintain vacuum of approximately 10 microns. This equipment is expected to be of great usefulness in the development of alloys for high-temperature service.

Throughout the history of General Electric, the Company's record of progress has been closely related to the development of its laboratory system. From modest beginnings these facilities have been expanded steadily and the projects now under way give every assurance that the Company's laboratories will continue to keep pace with the growing needs of American industry.

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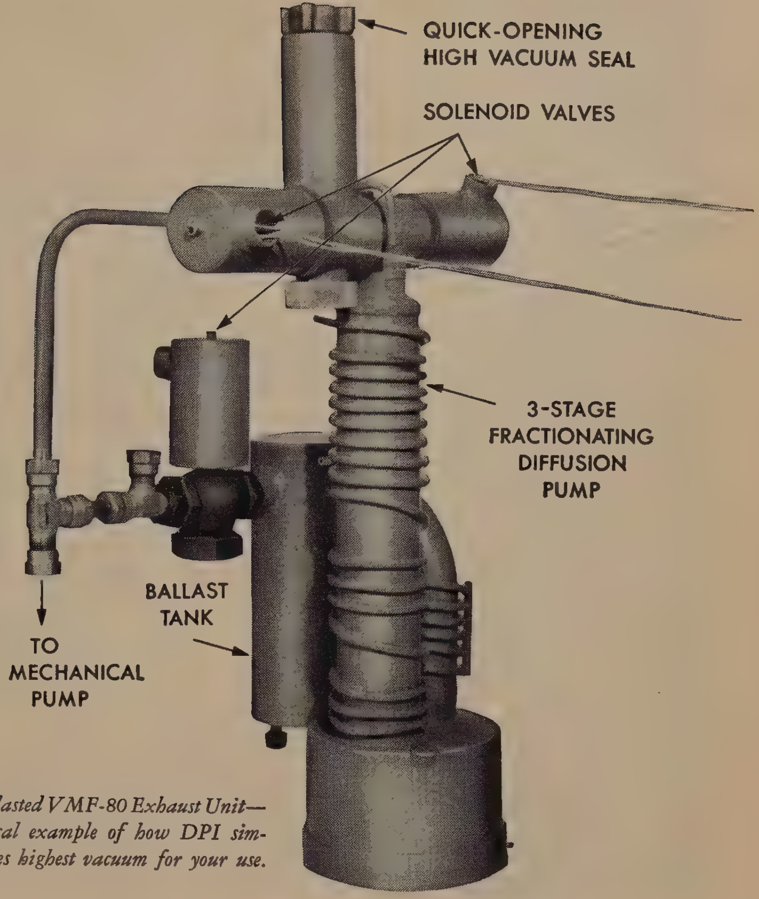
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We're no suckers for their slick, slave-state patter. We let them spout and then we let them have it — at the polls.

We're smart that way. In other ways, though, we're idiotically idealistic.

We have a knack of sitting back and waiting for "Pearl Harbors."

We were just plain lucky the first time. Another sneak attack will more than destroy our fleet.

War weapons have come a long way since Pearl Harbor. Planes fly faster over far greater distances, unseen, unheard — until it is too late.

Sure we have atom bombs. But they're not exclusive with us any more. And whoever drops them first delivers the knockout blow.

While we have converted our factories to peacetime service, elsewhere war production is still the number one industry.

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TUNING OF GROUND-FAULT NEUTRALIZERS

By application of basic principles, the proper reactance values to be selected can be determined without imposing a fault on the system. The accuracy of this method is confirmed by tests involving currents in a line-to-ground fault

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GROUND-FAULT neutralizers are in operation on power systems in this country at voltages from 2.4 kv through 140 kv. When being installed and operated, these neutralizers must be "tuned" to the system for satisfactory system operation.

A ground-fault neutralizer is a protective device which responds to single line-to-ground faults on "neutralizer-grounded" systems. The device is essentially a variable reactor with special characteristics and is connected between one or more transformer neutrals and ground. It is important that the basic principles of ground-fault neutralizer operation be understood before consideration is given to tuning methods.

BASIC PRINCIPLES OF OPERATION

The occurrence of a single line-to-ground fault on a three-phase power system that has all neutrals isolated with respect to ground causes the other two phases to rise to line-to-line voltage above ground as illustrated in FIG. 1. Line-to-ground charging currents, I_b and I_c, which lead their respective voltages, V_{ba} and V_{ca}, by 90 deg flow in each of these unfaulted phases. The vectorial sum of these currents, I_s, returns through the fault to the system. In the ideal case, this summation current leads the line-to-neutral voltage of the faulted phase by 90 deg. Therefore, the line-to-ground fault current on an isolated neutral system consists solely of the charging current to ground of the other two phases, except for a slight loss current.

When the system neutral is grounded through a ground-fault neutralizer, the ground-fault current is "neutralized." This is accomplished by neutralizing the capacitive current in the fault, I_s, by a component, I_n. The system neutral-to-ground voltage is displaced by the single line-to-ground fault and rises to the phase-to-neutral voltage of the faulted phase. This voltage, V_{na}, is impressed across the ground-fault neutralizer which is connected between the transformer neutral and ground. An inductive current, I_n, which lags this voltage by 90 deg and is limited in magnitude by the neutralizer reactance, tends to flow in the fault. This current is 180 deg out of phase with the capacitive current in the fault. With the ground-fault neutralizer properly tuned to the system, the inductive current through the neutralizer will be approximately equal to the capacitive ground-fault current. Hence, the current in the fault will be approximately zero, that is, "neutralized."

Complete neutralization of the fault current is not possible in practice. A residual current continues to flow in the fault owing to losses of the system and of the neutralizer, to nonexact tuning, and to harmonic components in the zero-sequence voltage. The magnitude of the residual fault current (rms value) can be expressed as follows:

$$I_f=(I_i^2+I_q^2+I_3^2+I_5^2+\ldots\ldots\ldots)^{1/2} \qquad (1)$$

where

I_f = Residual fault current
I_i = In-phase (nonreactive) component
I_q = Quadrature (reactive) component
I_3, I_5, etc. = Harmonic components

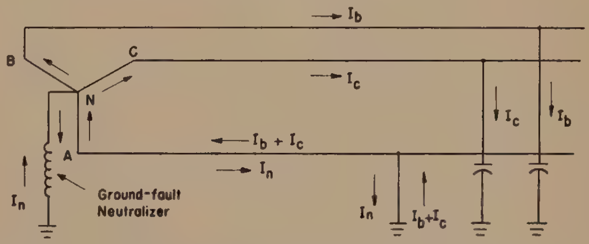


Fig. 1(A). Idealized ground-fault currents on ground-fault neutralizer system

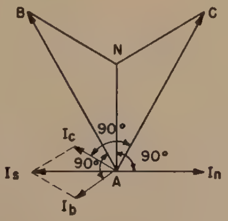


Fig. 1(B). Idealized vector relationships of voltages and currents indicated in Fig. 1(A)

With phase A grounded:
V_{BA} = Voltage of Phase B conductor above ground
V_{CA} = Voltage of Phase C conductor above ground
V_{NA} = Voltage across ground-fault neutralizer
I_b = Line-to-ground charging current of Phase B
I_c = Line-to-ground charging current of Phase C
I_s = Sum of I_b and I_c
I_n = Ground-fault neutralizer current (adjusted to be equal in magnitude to I_s)

This article is so paged that, without mutilating other articles, it can be readily removed for filing as a group of full-size consecutive pages.—EDITOR

Small in-phase components of current due to resistance, insulation leakage, and corona loss are introduced into the idealized case previously analyzed. All of these losses are added at the fault location. The insulation-leakage loss varies, particularly on overhead lines where they are influenced by weather and geographic location. This residual current component in the fault is not detrimental to the fault-extinguishing action of the ground-fault neutralizer.

Further, in practice, exact adjustment of the neutralizer is not generally accomplished. Neutralizers are furnished, generally, as tapped reactors, whereas the capacitances of the system can have any value depending on the value of the line constants. The capacitances of the system, in addition, will vary slightly with weather and seasonal changes. Hence, the vector sum of the capacitive current I_s and the neutralizer current I_n in FIG. 1 will introduce a component in the residual fault current. This component, within prescribed limits, is not detrimental to the fault-extinguishing action of the ground-fault neutralizer. The limits have been determined by experience and field tests, and these have indicated that neutralizers can be detuned plus or minus approximately 10 per cent.

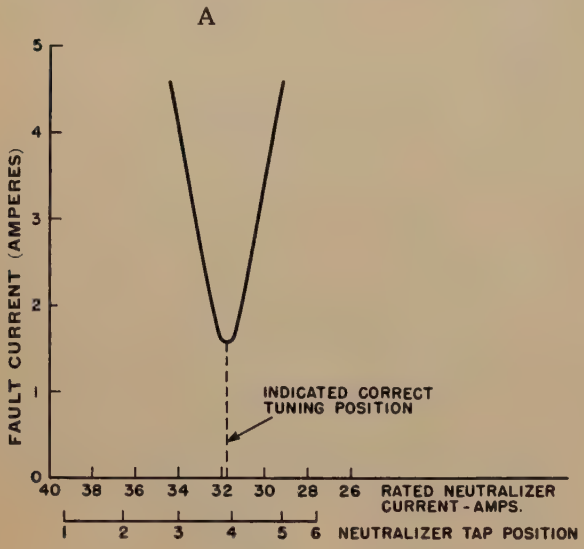


Fig. 2(A). Sample tuning curve for ground-fault neutralizer with a fault to ground on one conductor

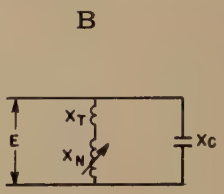


Fig. 2(B). Idealized schematic representation of circuit for tuning a ground-fault neutralizer with a fault to ground on one conductor

Harmonic components of the ground current are not influenced by the neutralizer adjustment, as neutralizers are tuned only to the fundamental frequency. The harmonic currents are caused by voltage harmonics which in turn are caused generally by corona and/or lightly loaded, highly saturated, transformers and, less frequently, by poor voltage characteristics of the generators. On the basis of experience, harmonic components have not been found to be detrimental to the fault-extinguishing action of the ground-fault neutralizer, although occasionally the harmonics substantially increase the residual current in the fault.

TUNING THE GROUND-FAULT NEUTRALIZER

The proper reactance setting of a ground-fault neutralizer to match the system capacitive reactance can be accomplished in several ways. The usual methods are the following:

(1). The neutralizer may be tuned to the connected system by solidly grounding one line conductor through a current transformer at any point on the system and recording fault current with the neutralizer set at successive values of reactance. The current transformer serves to isolate the ammeter from the system. The fault-current magnitude is determined by the factors indicated in FIG. 1 and Equation (1). FIG. 2A is a typical plot of fault current vs. rated neutralizer current.

Correct tuning is obtained at the neutralizer reactance setting which results in minimum current in the fault. The equivalent circuit for this method of tuning is shown in FIG. 2B, where the grounding transformer is represented by a fixed reactance X_T, the neutralizer is represented by a variable reactance X_N, and the transmission lines are represented by a capacitor X_C. All reactances considered are the appropriate zero-sequence values. The impressed voltage is approximately system line-to-neutral voltage. As in any parallel resonant circuit, the tuning point is indicated by minimum current in the external circuit.

(2). If it is not considered desirable to intentionally fault the system for the purpose of tuning the neutralizer, equally accurate results may be obtained by tuning without a fault. This method, however, makes necessary the consideration of several factors which may affect accuracy of results. These factors will be given consideration later. Since the capacitances to ground of the three phases of a system are rarely identical, the neutral point, with no fault on system and the system neutral isolated with respect to ground, will not be at ground potential. This voltage difference appears as E_o in the equivalent circuit shown in FIG. 3B and causes a current to flow through the neutralizer X_N, the transformer X_T, and the line capacitance X_C.

All reactances considered are the approximate zero-sequence values. When the neutralizer reactance is adjusted to a value equal to system capacitance, a series resonant condition exists and is indicated by maximum current flow in the neutralizer. A typical plot of neutralizer current vs. rated neutralizer current is shown in FIG. 3A. The magnitude of this current is limited by the resistance of the components of the series resonant circuit. This current reading is usually obtained by connecting an ammeter in series with the neutralizer.

On most systems where neutralizer tuning is performed by the method just described—that is, with no fault on the system—a current of several amperes will flow at the neutralizer reactance setting nearest resonance. This current will usually be between 5 percent and 25 percent of rated neutralizer current for that particular setting. Since $E=IZ$, it follows that voltage across the neutralizer for these currents will be 5 percent to 25 percent of normal (line-to-neutral) voltage. Apparent neutralizer reactance at these reduced voltage levels may differ from the reactance when full line-to-neutral voltage is impressed across the neutralizer. This difference in reactance is maximum at Tap 1 (maximum-rated-current tap) and decreases to zero at higher-numbered taps.

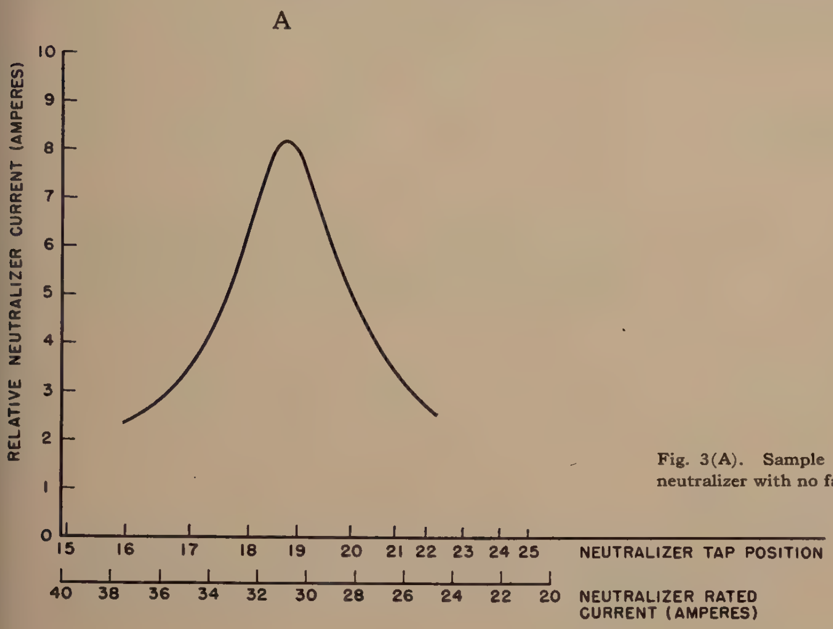


Fig. 3(A). Sample tuning curve for ground-fault neutralizer with no fault on the system

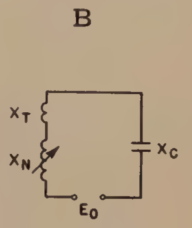


Fig. 3(B). Idealized schematic representation of circuit for tuning a ground-fault neutralizer with no fault at the system

The design factors which bring about the variation in reactance at different voltage levels will be considered briefly. A typical magnetization curve for core steel used in transformers or ground-fault neutralizers is shown in FIG. 4. For a 10-minute-rated neutralizer with the usual 25 tap positions, the relative flux density for normal operating conditions at various taps is approximately as indicated at the corresponding points marked on the curve. Note that Taps 11 through 25 fall on the portion of this curve which is essentially a straight line.

In most cases where, as noted previously, neutralizers are tuned without a fault being applied to the system, the voltage appearing across the neutralizer will be from 5 percent to 25 percent of normal. These points are indicated by *A* and *B* respectively which are also on the straight-line portion of the magnetization curve. It can be shown that, for any tap normally on the straight-line portion of the curve (Taps 11 through 25 in this case) the neutralizer reactance will have the same ohmic value when tested at any other point on the straight line portion of the magnetization curve. Thus, if the tuning test without a fault results in conditions between *A* and *B* on the curve and the indicated tuning is between Taps 11 to 25 inclusive, no correction is required. The correct tuning point for fault conditions will be the same as that obtained in tests without a fault.

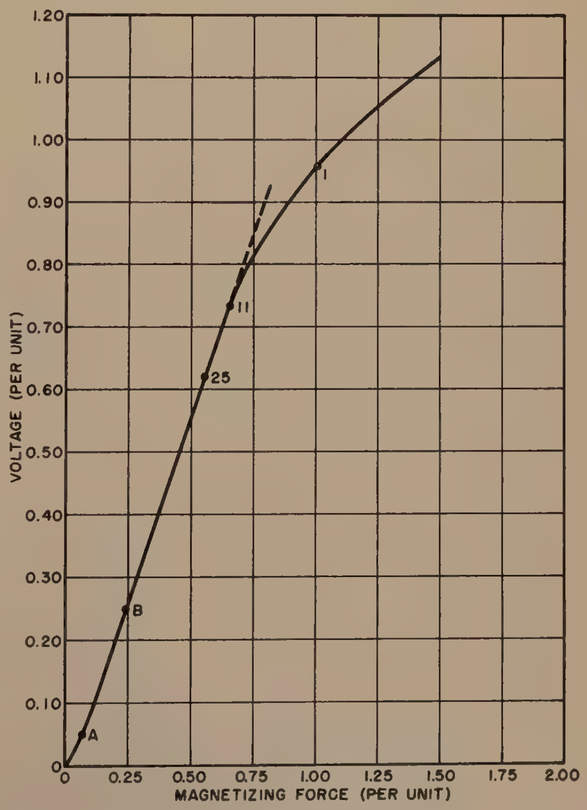


Fig. 4. Typical magnetization curve for core steel used in ground-fault neutralizers

The question now arises as to what procedure should be followed when the indicated tuning point without a fault is between Taps 1 and 11. It will be noted in Fig. 4 that these taps are on the upper bend of the magnetization curve. From previous comment upon neutralizer reactance at reduced voltage levels, it follows that the neutralizer reactance will *not* have the same ohmic value for test conditions between points A and B as it will for actual operating conditions between Taps 1 and 11 since the straight line relationship no longer exists. Fortunately, the characteristics of core steel are well defined and can be quite accurately predicted in the region of the upper bend of the magnetization curve.

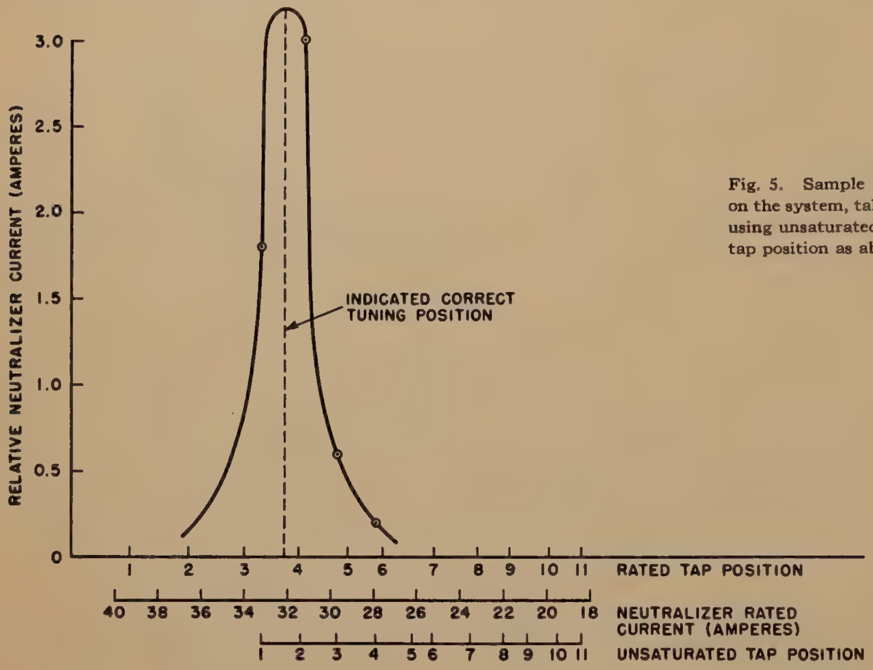


Fig. 5. Sample tuning curve for ground-fault neutralizer with no fault on the system, taking account of saturation calculations. Data are plotted using unsaturated tap position as abscissa; answer is obtained using rated tap position as abscissa

To permit accurate correction for those cases where the tuning test without fault indicates maximum current between Taps 1 and 11, the design engineer calculates a K factor for each neutralizer. This K factor may be in the order of 1.2 for a typical neutralizer and is the value by which nameplate ohms at Tap 1 should be multiplied to obtain apparent ohms at Tap 1 when tests are made at the lower voltage levels indicated between A and B in Fig. 4. For calculating the correct tuning point, this K factor should be decreased uniformly from the specified value at Tap 1 to a value of 1.0 at Tap 11.

Although the preceding treatment has dealt with a neutralizer having 25 tap positions, it should be noted that this is only one of several types of neutralizers. Tapped neutralizers may have a different number of tap positions. Neutralizers are also built with a continuously variable reactance. The case mentioned, in which $K=1.0$ at Tap 11, is a typical example for one type of neutralizer, but the K values may differ for other neutralizers. In any case, however, the same considerations apply, and specific values of K factor for any particular neutralizer may be obtained from the manufacturer.

The procedure followed in determining the correct tuning point is best described by an example from an installation on a 69-kv system. Table I shows readings taken during the tuning test with no fault on system. Since these readings indicate maximum current at Tap 2, the correction mentioned must be applied to determine the correct tuning point for the actual fault conditions. The K factor for this particular neutralizer is 1.185 and its use is shown in Table II for converting nameplate reactance to equivalent reactance X_E.

It should be noted that transformer zero-sequence reactance is shown in Fig. 3B as part of the tuned circuit. In calculating neutralizer current at various taps, it is necessary to add ⅓ of the transformer reactance to the neutralizer reactance. (This relation of transformer and neutralizer reactances can be determined from a consideration of symmetrical components.) In Table II the equivalent neutralizer current or unsaturated tap current is determined by the equation $I_E=E_{L\text{-}N}/(Z_E+\frac{1}{3}Z_{OT})$, where $E_{L\text{-}N}$ is the system line-to-neutral voltage, Z_E is the equivalent impedance of the neutralizer which, for practical purposes, is the same as equivalent reactance X_E of the neutralizer; Z_{OT} is the transformer zero-sequence impedance.

The data shown in Table II are used in Fig. 5 for determining the correct tuning position. Note that the

TABLE I

CURRENT READINGS TAKEN DURING TUNING TESTS

Tap No.	Neutralizer Current
1	1.8 amp
2	3.0 amp
3	0.6 amp
4	0.2 amp

neutralizer rated current has been indicated along the abscissa, together with corresponding rated tap positions from the nameplate data. Unsaturated tap positions are also shown at points corresponding to the equivalent current in Table II. The relative displacement of rated tap positions and unsaturated tap positions shows graphically the effect of saturation. Test values from Table I are now plotted on Fig. 5 using unsaturated tap position as the abscissa and rated neutralizer current as the ordinate. A symmetrical curve through these points will indicate the tuning position at the maximum point. The *rated* tap position nearest this point is the proper setting for fault conditions for the system mileage in service. In this case, the neutralizer should be set on Tap Position 4.

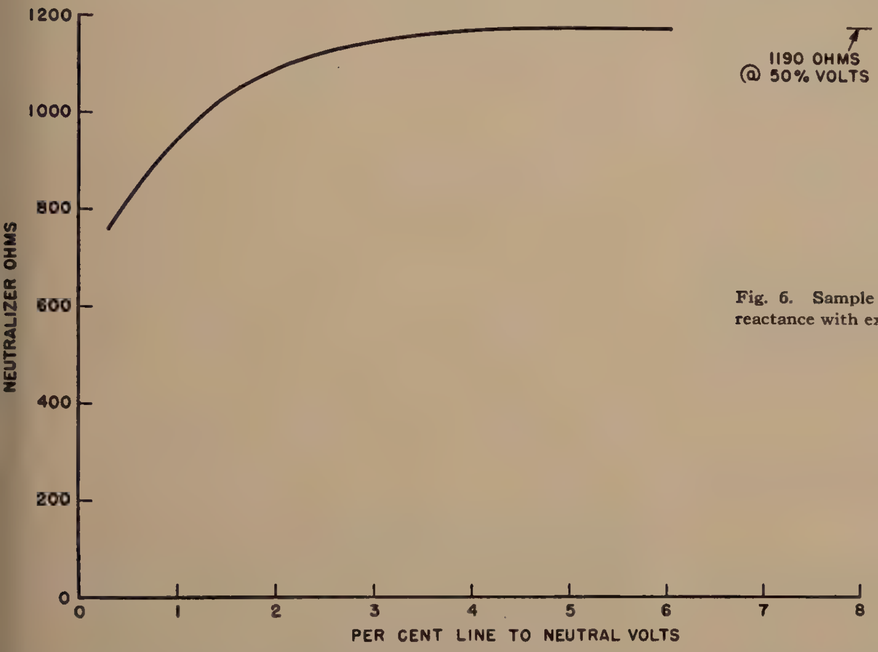


Fig. 6. Sample curve indicating variation of ground-fault neutralizer reactance with excitation

In cases where the curve indicates a tuning point midway between two taps, the tap having the smaller number should be used. After tests without a fault on the neutralizer were completed, in the example just given, a fault was applied to the system and a second set of tuning data was taken as described previously. The curve obtained is that shown in Fig. 2A; and it verifies that tap position 4 is the optimum tuning point for fault conditions. Other neutralizers have been tuned by both methods and the accuracy with which the results have checked indicates that the results that have been obtained by tuning with no fault on system are very reliable.

Referring again to Fig. 4, it will be noted that a slight curvature is shown at the lower end of the magnetization curve. Under certain conditions, this introduces another factor which must be considered when a neutralizer is being tuned with no fault on the system. It was mentioned earlier that, for this type of tuning test, the maximum voltage across the neutralizer will usually be between 5 percent and 25 percent of the system line-to-neutral voltage. However, there have been cases on well-transposed systems where this voltage at the resonant point is less than one percent. This results from the nearly perfect balance of the system phase-to-ground capacitances which limits the voltage of unbalance E_o (Fig. 3B) to an extremely small value. Tuning tests under these conditions would cause operation to take place close to the origin of the curve shown in Fig. 4.

Theories, substantiated by tests, indicate that core steel characteristics are not accurately predictable in this region. The magnetization curve for one core may have an appreciable curvature near the origin while for another identical core design, it may approach a straight line. The effect on measured neutralizer reactance is shown in Fig. 6 which indicates that voltage should be greater than 3 or 4 percent to obtain correct tuning results.

Since this condition results from a low value of E_o (Fig. 3B), it can be readily changed by temporarily increasing E_o during the tuning tests. On a low-voltage system this could be done by connecting a capacitor from one phase to ground to produce an intentional unbalance and larger E_o. However, many neutralizers

TABLE II

CALCULATED NEUTRALIZER CURRENTS

Tap No.	Nameplate Reactance	*K* Factor	Equivalent Reactance	Equivalent Current
1	995	1.185	1180	33.2
2	1070	1.166	1248	31.4
3	1152	1.148	1322	29.7
4	1247	1.130	1410	27.9
5	1349	1.111	1499	26.2
6	1422	1.092	1552	25.3
7	1562	1.074	1678	23.5
8	1695	1.056	1788	22.0
9	1820	1.037	1885	20.9
10	1990	1.018	2025	19.5
11	2145	1.000	2145	18.4

are installed on systems above the voltage rating of available capacitors, so a more direct approach is necessary. On 69-kv installations where this tuning condition existed, an auxiliary transformer was connected as shown in Fig. 7. This transformer was rated 1 kva, 115/230V, 115/230V. By selecting proper connections, the existing voltage E_o can be bucked or boosted to the point where tuning-test data can be taken on the straight-line portion of magnetization curve.

On a recent 69-kv installation, data for three tuning curves were taken. The first, with no fault on the system, indicated the tuning point at Tap 20, but the voltage across the neutralizer on this tap was 1.3 percent of the system line-to-neutral voltage. The auxiliary transformer was temporarily connected in circuit and a repeat test showed the tuning point at Tap 19 with 24 percent voltage across the neutralizer. The third test with a single line-to-ground fault on the system also showed the tuning point at Tap 19, thus confirming the results obtained with the auxiliary transformer.

It should be noted that the voltage E_o is related to the voltage across the neutralizer by the system amplification factor. An average system may have an amplification factor of 10 to 20, which means that the voltage appearing across the neutralizer when tuned to the system will be approximately 10 to 20 times the voltage E_o. Thus the 115 or 230 volts injected in circuit by the auxiliary transformer can cause much larger voltages across the neutralizer.

DATA FOR OPERATION

At the time the neutralizer is installed, tuning tests are made with no fault on the system. If the user so desires, additional tuning tests are made with single line-to-ground fault on the system. These tests are usually made for only one condition of connected system mileage. Data obtained from this one condition can be used to determine correct neutralizer setting for any other system mileage within the current range of the neutralizer. In Fig. 5, it should be noted that the indicated correct tuning position occurs at a neutralizer current value of 32 amp for 82.6 miles of 69 kv transmission line. This corresponds to an average charging current for the system of 32/82.6 or 0.388 amp per mile. Based on this value a curve of the type shown in Fig. 8 can be drawn to show correct neutralizer tap position as a function of connected system mileage. In this case the neutralizer will properly tune a maximum system of 101 miles of line when set on Tap Position 1, and a minimum system of 20 miles of line when set on Tap Position 25. Note that a straight-line relationship is used between system mileage and neutralizer current, since this average condition will usually exist even though several types of line construction may be used for various parts of the system.

On a recent installation, tuning tests were made for eleven different system-switching conditions. Each of these conditions involved different combinations of line mileage and line construction for a 34.5-kv system. Fig. 9 shows that the tuning points for these fall essentially on a straight line and confirms the procedure followed for obtaining the curve shown in Fig. 8.

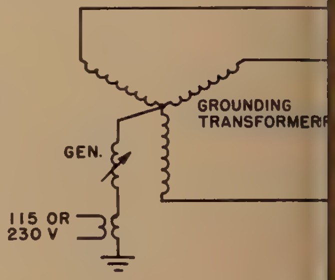


Fig. 7. Schematic diagram for connection of auxiliary transformer used to increase excitation voltage during tuning tests

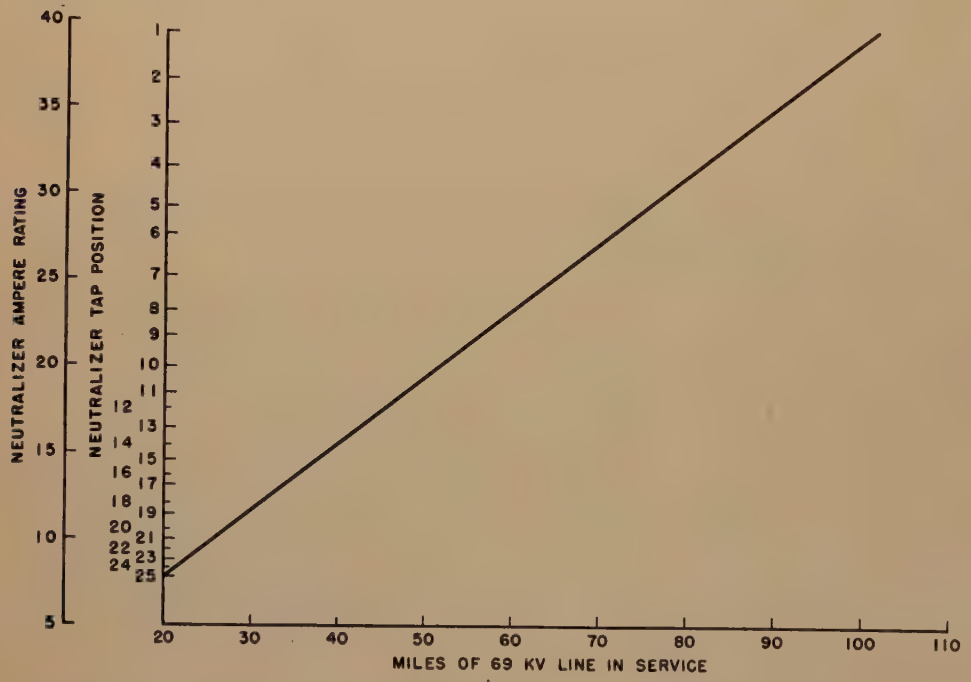


Fig. 8. Example of curve illustrating ground-fault neutralizer tap position vs miles of 69-kv line in service

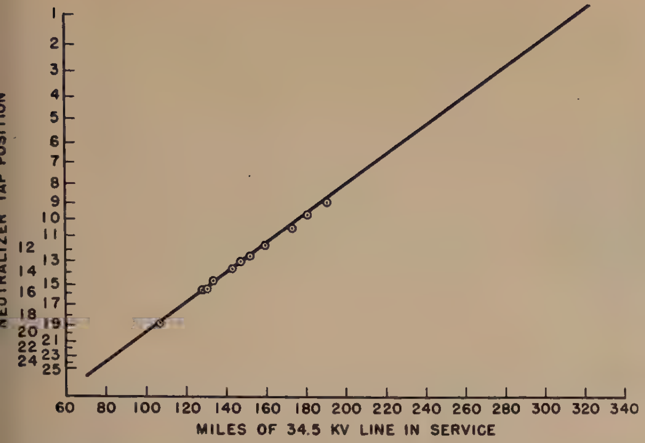
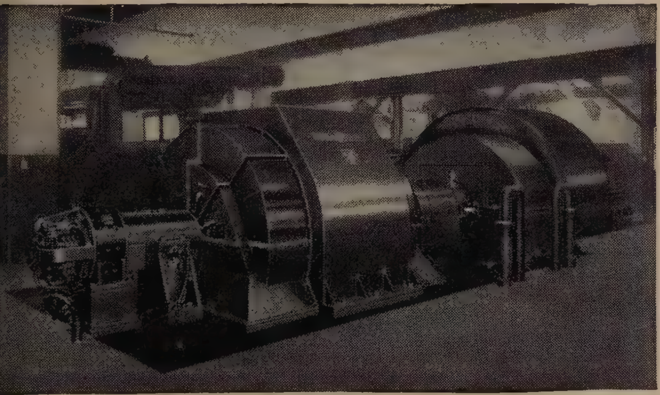


Fig. 9. Ground-fault neutralizer tap position vs line mileage curve showing correlation of tuning test data on a composite curve. Each point represents a tuning test for the line mileage indicated as abscissa

The proper ground-fault neutralizer reactance for a system can be determined with equally accurate results y either of two tuning methods:

(1). Adjusting for minimum fault current in a line-to-round fault.

(2). Adjusting for maximum current in the neutralizer without a fault on the system by making use of the system voltage of unbalance. To tune by this method may require correction for saturation at the upper end f the magnetization curve or for insufficient excitation at the lower end of the magnetization curve as was escribed in this article.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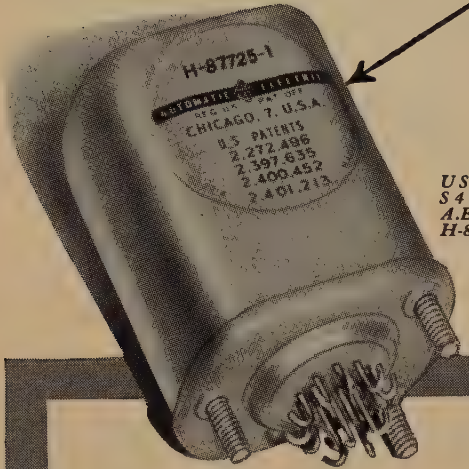

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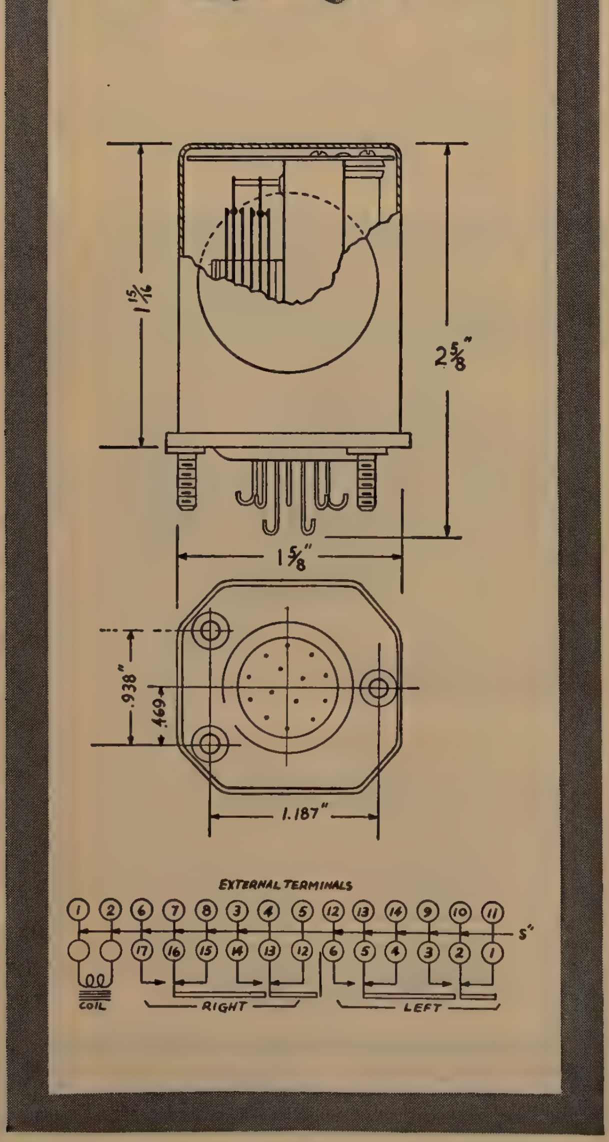

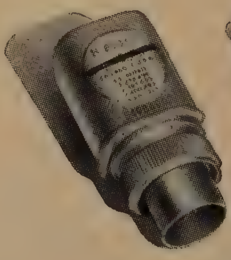

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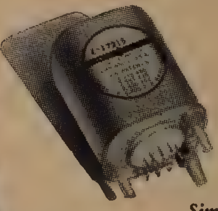

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MAGNETIC FLUID CLUTCH

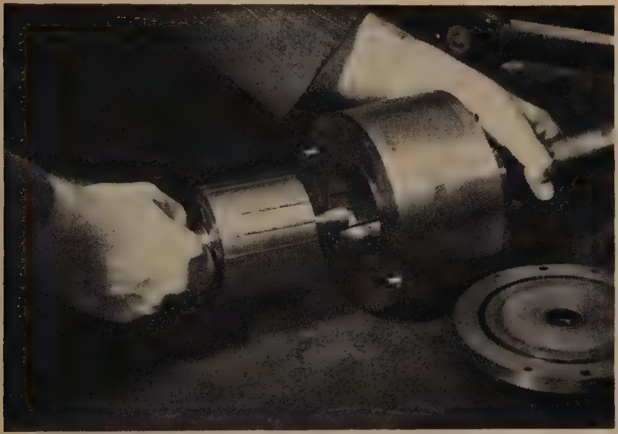
New type of coupling, in which magnetic fluids are used for binding together two parallel surfaces. Laboratory tests demonstrate such advantages as low energizing power, smooth control, large heat capacity, and simplicity of design

By K. E. WAKEFIELD
General Engineering and Consulting Laboratory
General Electric Company

Kenneth E. Wakefield

MUCH interest has been evidenced in the National Bureau of Standards' recent report that so-called "magnetic" fluids, consisting of finely divided iron powder mixed with light oil, can be utilized with great efficacy as a medium for binding together two parallel surfaces between which a magnetic field has been produced. Such an arrangement can be readily set up in the form of a clutch and, because of this, the mechanism became known as the "magnetic fluid clutch."

Investigation and evaluation of this new type of coupling began immediately. Various groups in the General Electric Company have been working on different phases and uses, including studies of units for servomechanisms and other applications involving the use of clutches of small sizes. The results of one such investigation, pertaining to the use of permanent magnets in the clutch, have been outlined by R. J. Parker of the Chemical Department.⁽¹⁾



Magnetic fluid clutch of the cylindrical type, partially disassembled; the gap between cylinders prevents interlocking. Such a clutch will transmit 40 hp at 1800 rpm

The General Engineering and Consulting Laboratory, in addition to participating in studies of the clutch for small applications, has conducted an investigation of the magnetic-fluid-clutch principle as applied to braking and clutching devices that are capable of handling amounts of power ranging up to several thousand horsepower. Such clutches may be used, for example, in conjunction with large diesel engines or for rapid reversing of marine drives. However, much of the information obtained during this study is of a general nature and, hence, of use in designing units for a wide variety of applications such as brakes, clutches, dynamometers, servoamplifiers, cushioning devices, and speed controls.

This article describes the results of that investigation and includes illustrations to clarify the description and enable the engineer to determine the approximate physical sizes for various clutch ratings. Included also are references to basic information published by the National Bureau of Standards. The tests on the iron-oil mixtures containing wetting agents and thixotropic agents were made by the Research Laboratory.

PRINCIPLE OF OPERATION

The magnetic fluid clutch consists primarily of two parallel magnetic surfaces separated by a small gap that is filled with a mixture of oil and finely divided iron powder. The surfaces may be two parallel disks or concentric cylinders, each rotating independently of the other about a common axis. The unit contains a coil to produce magnetic flux in the region between the surfaces; and a return path for the flux is provided. Provision is also made to seal in the iron-oil mixture to prevent leakage.

If no magnetic field is present, the force restraining relative motion between the two surfaces is produced only by the viscous drag. In the presence of a magnetic field, however, the fluid seemingly solidifies and the restraining force becomes very great. Thus, the device adapts itself well to a clutching or braking operation. It generally is referred to as the magnetic fluid clutch, in spite of the fact that in many applications it is not used strictly as a clutch.

There are a number of theories explaining what happens when the mixture is magnetized. The magnetized fluid exhibits a very high resistance to flow and appears striated when stressed. There is some evidence that under slip conditions, slippage occurs at the surfaces of the clutch plates, but this has not yet been definitely established. Tests have been made with various surface conditions by the National Bureau of Standards, and the Bureau reports that no change in tangential force is experienced when the surfaces are polished, ordinary lathe-finished, or roughened.

This article is so paged that, without mutilating other articles, it can be readily removed for filing as a group of full-size consecutive pages.—EDITOR

⁽¹⁾ "Permanent Magnets in Drag Devices and Torque-transmitting Couplings," by R. J. Parker, GENERAL ELECTRIC REVIEW, vol. 52, Sept. 1949.

The Bureau further reports that serrated surfaces reduce the tangential force. However, the laboratory with which the author is associated has built a model having small, widely spaced rectangular teeth—placed at right angles to the direction of motion—on both surfaces of the clutch, and tests with this model indicate that the tangential force is increased, especially at higher flux densities. These teeth are only 0.020 inch high, 0.032 inch wide, and about 0.625 inch apart. More complete tests will be necessary to determine definitely whether the improvement is sufficient to warrant the use of the toothed surfaces.

Tangential force seems to be independent of the viscosity of the suspension medium; hence, silicone oils having a low viscosity and high flash point would be suitable for applications in which a low value of viscous drag is of paramount importance. The viscosity of the fluid mixture has been measured and found to be from four to ten times that of the oil alone.

In tests where the rate of slippage was relatively high (up to 1800 rpm) no noticeable change in tangential force was noted with time. In other tests, however, in which the slippage was three to twelve revolutions per minute, the torque increased with time and then leveled off. This seemed to be due to a shifting of iron particles in the gap. When the magnetizing current was shut off, the tangential force did not immediately return to the original nonenergized value but took on a value several times the original; then it dropped slowly at much the same rate as the rise with respect to time. These effects seem to indicate that some packing occurs while the clutch is in operation and that the amount of packing is a function of the amount of slippage.

In all tests stable values were obtained if one member was rotated 200 to 300 times relative to the other. Thus, since most applications are at 1800 or more revolutions per minute, this effect would be of importance only when the required time of reaction was less than ten seconds. On the other hand, when the clutch was energized, the tangential force immediately rose, in all tests, to more than 75 percent of the final value, the 200 revolutions being the interval to go to 100 percent of the final value. Measurements made by the National Bureau of Standards to determine the response time revealed that for one model the rise of tangential force and the rise of current occurred within one millisecond of each other. In the absence of our knowledge of the conditions under which these tests were conducted, it seems at present advisable to use the initial value of tangential force (about 75 percent) in designing, rather than the stable value (100 percent), although this calls for a 25-percent increase in clutch weight.

In most of the tests made by the author's laboratory, mixtures containing five parts of carbonyl "E" iron to one part of SAE 10 petroleum oil, by weight, were used. In addition, tests were made with ratios of seven to one, carbonyl "E" to SAE 10 petroleum oil; and ratios of five and seven to one, carbonyl "E" to silicone oil LTNV-20. The cylindrical-type clutch was used in all tests made by the laboratory. Dynamic as well as static tests were run, although later developments indicated that static tests were sufficient to give much of the information desired.

PHYSICAL DESIGN

Most magnetic-fluid-clutch designs are of two basic categories, the cylindrical and disk types. For most applications the cylindrical type is probably preferable, although in some cases the disk type may also be suitable. Under high-speed conditions, however, the latter type would lock in, since the iron tends to move to the outside; under similar speed conditions the cylindrical type may fail to transmit full torque, but it is doubtful that the clutch would fail completely. For a given torque capacity the cylindrical type is somewhat smaller than the disk type in both length and diameter, with a consequent saving in weight. Furthermore, the presence of thrust forces in the disk type makes its design necessarily more complex.

The use of multiple-surface units could be justified only when such a unit would not unduly increase the coil size. Where viscous drag must be low, the coil is already a substantial portion of the clutch as far as weight is concerned; in such cases, multiple-surface units would be out of the question. Furthermore, thrust problems similar to those encountered in the disk type would have to be solved. Clutches in tandem may be resorted to if very high torques at high speeds or limited diameter are required.

A sketch showing the arrangement of the component parts of a cylindrical-type clutch is shown in Fig. 1.

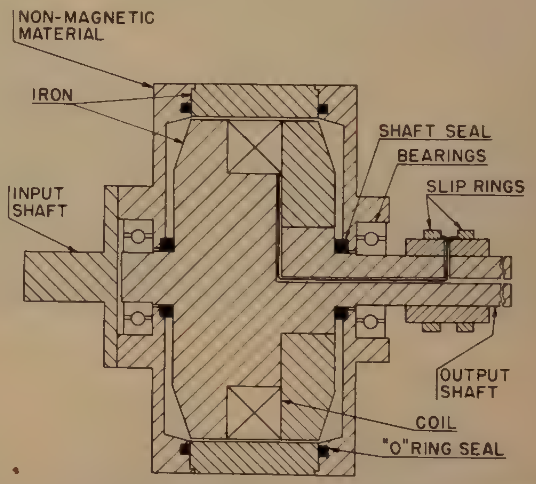


Fig. 1. Cross section of a magnetic fluid clutch showing the arrangement of component parts

It should be noted that this illustration is presented for explanatory purposes only, and that an actual design may vary from the drawing to meet specific requirements. Fig. 2 shows a representative torque curve such as might be obtained from a clutch similar to the one illustrated.

The two curves shown in Fig. 3 indicate the expected diameter and length of a clutch which would transmit any given amount of torque from 1 to 10,000 lb-ft, with a viscous drag, at 1800 rpm slip, of one percent of rated torque. These curves are representative, and would be strictly applicable only to situations in which the amount of slippage under energized conditions is small, or in which the duration of full-load slip is very short. For heavier duty, the sizes would necessarily be larger to provide for the requisite heat capacity.

ADVANTAGES OVER OTHER TYPES OF CLUTCH

The apparent advantages of the magnetic fluid clutch over other types are as follows:

(1). There is little or no wearing of the clutch surfaces; and even if there were, the net effect would merely be to have a little more iron in the mixture at a slightly larger gap. This seems to be a decided improvement over the dry friction clutch, on which surfaces must be replaced at intervals because of wear.

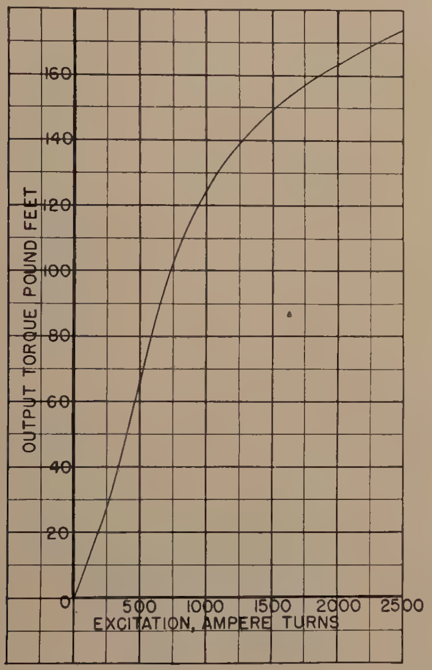


Fig. 2. Typical torque curve for a clutch having the general proportions of that shown in Fig. 1 and a diameter of six inches. The coil is rated 1250 ampere-turns

(2). Small energizing power is required for controlling large amounts of output power. The possibility of using alternating current has not been investigated; however, this would necessitate the use of laminations, and simplicity of design seems to dictate the use of direct current. Simple rectifying elements could be used to convert to direct current if it were advisable or necessary to use an a-c source, since the power requirement is small.

(3). Control is simple, smooth, and positive. Linear characteristics can be obtained, although experience has shown that slight variations of torque for a given current occur from day to day.

(4). There are no moving parts to maintain other than the bearings themselves and, in some applications, slip rings.

(5). The clutch lends itself to applications in which heavy loads are brought up to speed from a standstill, and also as a brake, since by proper design the heat capacity can be made very large.

(6). The static and slipping torques are the same, and as a result the clutch is free from chatter. Any exceptions that have been found to exist occurred where the slipping torque was greater than the static torque. However, it is possible that this may have been due to the difficulty of measuring the maximum torque transmitted without slip.

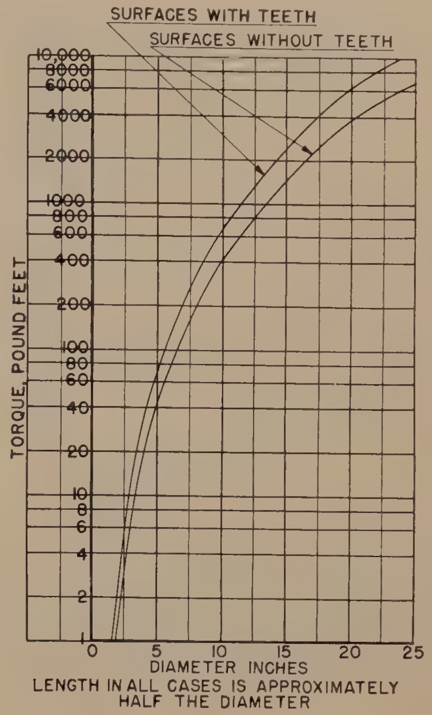


Fig. 3. Approximate sizes of cylindrical-type clutches rated from 1 to 10,000 lb-ft torque, using a 5:1 ratio of carbonyl "E" to silicone oil LTNV-20 and having a viscous drag, at 1800 rpm slip, of approximately one percent of rated torque

(7). The magnetic fluid clutch is a safety device when used between the motor and load for applications in which sudden loading may occur. The clutch will slip while still transmitting maximum torque, thus cushioning severe shocks and preventing excessive overloads.

(8). The clutch is of simple construction, consisting of a driven member and a driving member whose relative positions (except for rotation) are unchanged.

INHERENT DISADVANTAGES

The disadvantages of the magnetic fluid clutch to which there seem to be no ready solutions at the present time are:

(1). This clutch is somewhat larger in size and weight than a friction clutch of equal torque capacity.

(2). The clutch will become inoperative if the coil should burn out, or in case of electrical failure. With proper design a coil can carry many times its rated current for a short time with no damage. But if the clutch is overheated by excessive loading to the extent that the coil is damaged, the resultant cost of repair would be high in comparison to the cost of damage done to a friction clutch under similar conditions of overload.

(3). The iron-oil mixture must be sealed in to prevent loss of oil and subsequent drying-out of the mixture as well as to prevent the iron particles from damaging the bearings. This is a drawback because of the great care necessary to provide adequate seals, and because a "fool-proof" seal which can be universally used for this application has not as yet been found.

(4). Little information is available as to the effect of very high speeds on the mixture. This may or may not be a serious handicap since the effect of thixotropic agents under these conditions has not been studied. The National Bureau of Standards, however, is reported to have built a model having a diameter of four inches which operates at 10,000 rpm. Details of this design are not available at the present time.

(5). It is impossible to isolate one member from the other by means of a diaphragm, as contrasted to certain other types of magnetic couplings.

SPECIAL DESIGN PROBLEMS

The following are special problems which must be taken into account in the design of these clutches:

(1). The most important of these problems is the fact that the iron-oil mixture settles out on standing, even in a matter of hours. The mixture becomes a layer of oil on a hard cake of iron particles, which, if present in a clutch, may lock the surfaces together, even with no magnetization. This can be solved in two ways: One way is to use a wetting agent which surrounds each particle with a layer of fluid; this hastens the settling-out but prevents caking, so that with a little mixing the fluid is a homogeneous mixture again. The second way is to use a thixotropic agent. This method produces a mixture which will not change its shape unless agitated. The viscosity is a function of the shear force on the fluid, and even after weeks of standing the mixture remains homogeneous except for a very thin layer of oil which appears in some cases. The second of these methods is the one used by the laboratory at the present time. The effectiveness of the additive will determine whether the clutch can be operated at high speeds where centrifuging tends to occur.

(2). Unless precautions are taken, the iron may react chemically to substances in the fluid itself, with a subsequent loss in permeability and obtainable tangential force. The chief offender seems to be the presence of sulfur in motor oils; the use of other types of oils seems desirable for this reason.

(3). Viscous drag under nonenergized conditions must be very low in some applications. Since tangential force for any mixture is chiefly a function of the flux density, nonenergized drag can be reduced by increasing the gap length (thus increasing the size of the coil necessary). This will be reflected as an increase in the over-all clutch size, but not to an excessive extent. The viscosity of the fluid is a function of the iron-oil ratio; in fact, high iron-oil ratios tend to become grainy while not exhibiting very much of an increase in tangential force. A ratio of five to one seems to be a happy medium wherein the fluid is not too viscous, yet torque is high. In laboratory tests, seven-to-one ratios gave very little increase (less than ten percent) over five-to-one ratios in transmitted torque for a given flux density. A point to keep in mind, however, is that the coil size for seven-to-one ratios is about ten percent smaller than for the five-to-one ratios.

The proper selection of fluids is very important, and silicone oils of low viscosity and high flash and flame points seem well adapted to this use. Other oils which have been suggested for low-temperature applications are Army-Navy winterized oils, and sperm-oil derivatives. Steam-cylinder oils, Penn bright-stock oils, and Army-Navy high-temperature oils have been suggested for high-temperature applications.

(4). Special care must be taken to seal the fluid in the chamber to prevent possible damage to bearings and loss of oil. "O" rings have been used successfully in stationary applications, and Garlock Klozure seals in conjunction with a magnetic trap for shaft seals. Slinger arrangements are possible with nonvolatile fluids; however, this necessitates the construction of special baffles, etc., to prevent leakage at standstill. If positive seals are used, the pressure builds up in the clutch as the temperature rises; and unless this factor is considered in the design, the oil will eventually force a seal. Limiting the volume of the mixture to the volume of the gap may be sufficient to prevent this. Slinger arrangements are advantageous in that they automatically release the pressure.

(5). If the clutch is to be used under conditions of slippage, the heat-dissipation problem is probably the most important factor in design. Proper selection of oils is again important, for safety as well as operational reasons. It does not seem advisable to use the clutch as a speed regulator (under constant slippage) since considerable power is then wasted in the clutch. The clutch, however, lends itself readily to designs in which it is able to absorb large amounts of energy at intervals. The limitation here, of course, is the ability of the clutch to dissipate the heat generated within it.

(6). Much interest has been evidenced in various phases of the problem of time response. In general, the time lag between input voltage and output torque is governed chiefly by the electrical properties of the coil (inductance and resistance). Input current and output torque occur almost simultaneously, except for the packing effect described previously. For servo systems, the only approach to reduction of time lag seems to be to reduce the time constant of the coil as much as ossible; for power applications, however, the time of esponse may be reduced still further by the choice of lectric circuit used. Here the limitation lies in the nterval required between the instant of de-energiza-ion and the instant when it is desired to energize the lutch again. A lapse of perhaps three or four seconds nay be necessary to allow for the proper switching to eturn the control circuit to the condition required to nergize the coil.

PPLICATIONS

A partial list of suggested applications of this device ncludes:

(1). A clutching unit where sturdiness, ease of control, simplicity of operation, and low maintenance are required

(2). Braking operations, where relative motion between two members must be stopped

(3). Dynamometers and other power-absorbing devices, preferably having one member stationary

(4). A torque source in connection with which power amplification and linear characteristics can be obtained for servo-system applications

(5). Cushioning devices to absorb severe shocks

(6). Speed controls in which the clutch is operated at continuous slip

(7). Tension devices such as might be used in wire-making equipment or textile mills.

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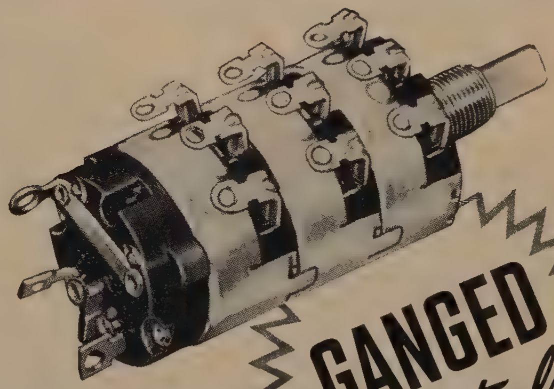

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PROTECTIVE ATMOSPHERES IN INDUSTRY . . Part X

Typical heat-treatment applications. New and interesting methods for bright-annealing metals, which result in improved quality, shortened manufacturing cycles, reduced costs, and other attendant advantages

By A. G. HOTCHKISS and H. M. WEBBER
Industrial Heating Divisions, General Electric Company

PROTECTIVE atmospheres, as indicated in Table II*, are utilized for a variety of industrial needs. A resumé covering a variety of applications of protective atmospheres will now be given, explaining where, why, and how they are used to advantage.

HEAT-TREATMENT IN FURNACES

A major classification of the uses of protective atmospheres is for the heat-treatment of metals. Typical applications are bright-annealing or normalizing, scale-free hardening, electric-furnace brazing, and operations in the powder-metallurgy industry, such as annealing of powders during their manufacture and the sintering of pressed-powder compacts.

The retaining of bright surfaces on metals during heat-treatment prevents loss of the metal from oxidation and eliminates or minimizes cleaning operations, such as pickling, grinding, or machining. Prevention of surface decarburization assures hardness at the surfaces of the parts, when heat-treated; if decarburized, the surface skin may require removal by subsequent grinding or machining operations.

Reducing atmospheres are desirable in electric-furnace brazing to clean the surfaces and encourage wetting of brazing metals on the parent metals, and thus aid capillary attraction. In this respect, the protective atmosphere serves the purpose of a solvent flux, such as is used in other heating methods for brazing. Reducing atmospheres are also desirable in the annealing of powders to reduce any oxides present and render the powders more suitable for subsequent pressing and sintering operations. The same reducing property is desirable during sintering to minimize oxides and encourage maximum surface diffusion of the powdered constituents. Reducing atmospheres also play a prominent part in the reduction of iron oxides surfaces of steel stampings when annealed in protect atmosphere furnaces, prior to porcelain enameli eliminating acid pickling operations and benefit by attendant advantages.

Protective atmospheres with various degrees of c bon potential are utilized with success; for example, gas carburizing, the atmospheres are utilized to repl other methods of imparting high-carbon cases on lo carbon steel parts, for casehardening. Also in carbo restoration treatments, atmospheres with carefu controlled carbon potential are useful for restori carbon to surfaces of medium- or high-carbon ste which have been decarburized in previous operation

Such uses of protective atmospheres often result t improved quality, shortened manufacturing cycl and reduced costs. It will be shown in this Part h these desirable results are accomplished in annealii the first of these heat-treating processes to be co sidered.

ANNEALING

Low-carbon Coiled Strip

An accepted method for bright-annealing cold-rol low-carbon steel strip in coils(6) is to heat and cool bell-type furnaces, such as the installation shown FIG. 117. Coils are stacked on a load-supporting ba with typical loads ranging from 6 to 18 tons in a sin stack. The steel is heated to temperatures of 1200 1400 F. Cycles vary with dimensions and weight of t load, but typical cycles are:

6-ton load: Heat to 1400 F in 13 hr, cool to 300 in 22 hr

16-ton load: Heat to 1400 F in 22 hr, cool to 300 in 32 hr

The protective atmosphere is commonly low-ra combusted gas (E1a in Table I) consisting of about percent CO_2, 10 percent CO, 15 percent H_2, 1.5 perce CH_4, and 68.5 percent N_2. If the cooling-water te perature is sufficiently low, the saturated gas from t atmosphere-gas converter is satisfactory; but if t cooling-water temperature is high (above about +70 the gas is commonly refrigerated to a dew point about +40 F.

Advantages of protective-atmosphere annealing this method are: Bright finish of the strip as anneale relatively fast time cycle, which shortens the man

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*The following will facilitate the location of material published in earlier parts of this serial:

Part	*Issue*	*Figs.*	*Equations*	*Tables*	*Footnotes*
Part I	Nov. 1948, p. 29	1 to 6	None	I and II	None
Part II	Dec. 1948, p. 41	7 to 14	(1) to (18)	III and IV	(1) to (9)
Part III	Feb. 1949, p. 37	15 to 23	None	V and VI	None
Part IV	Mar. 1949, p. 25	24 to 35	None	VII	None
Part V	Apr. 1949, p. 25	36 to 41	None	VIII to X	(10 and (11)
Part VI	May 1949, p. 30	42 to 54	None	XI to XII	(12)
Part VII	June 1949, p. 33	55 to 70	None	XIII to XV	(13) to (17)
Part VIII	July 1949, p. 32	71 to 89	None	XVI	(18) to (23)
Part IX	Aug. 1949, p. 26	90 to 97	None	None	None
Part X	Sept. 1949, p. 38	98 to 108	None	XVII to XIX	(24) and (25)
Part XI	Nov. 1949, p. 30	109 to 116	None	None	(26) to (29)

This article is so paged that, without mutilating other articles, it can be readily removed for filing as a group of full-size consecutive pages.—EDITOR

facturing cycle and shipping schedule; good operating economy; minimum labor; excellent uniformity of annealing throughout the stack; flexibility for treating various types of loads; and low over-all annealing cost.

Each load-supporting base has a pedestal of cast heat-resisting alloy, beneath which is a motor-operated fan for circulating the protective atmosphere throughout the charge. There is also a liquid seal around the periphery of the base. After the base is loaded, a sheet-metal alloy retort is put down over the charge, which engages with the water seal, giving a gas-tight chamber around the work. The retort is then purged with protective atmosphere, and the hot bell furnace is set down over it. After the charge is heated and thoroughly soaked through, the bell furnace is lifted and transferred to another charge. The load just heated is then allowed to cool in the room. A water-cooling coil is usually placed around the top to spray water on the sides of the retort to accelerate cooling. The cooling time of 31 hr was shortened 7 hr to 24 by means of this water-spray feature as shown by the typical example in Fig. 118, with a load of 12½ tons. The hood is removed after the cooling period, and the strip is taken from the base, following which the operating cycle is repeated.

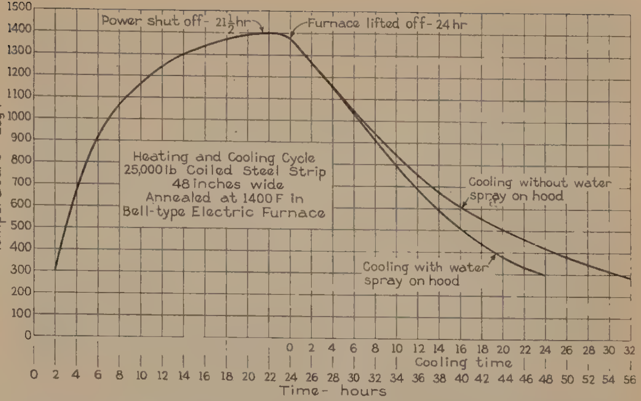

Fig. 118. Typical heating-and-cooling cycle in bell-type electric furnace, annealing low-carbon steel strip. Shortened cycle from spraying water on hood is shown at right

Coiled Tin-plate Strip

Coiled steel strip for tin plate has commonly been annealed in multiple-stack bell-type furnaces in protective atmospheres of low-ratio combusted gas (refrigerated). These atmospheres have resulted in surfaces on the strip which are clean and apparently free from oxide. After the strip had been plated, however, it was found that invisible oxides—which are formed particularly near the exposed edges, during the annealing—affect the quality and corrosion resistance of the material. It has been found, moreover, that by using a different atmosphere, such as high-ratio Neutralene (E2b in Table I), the invisible oxides do not form, and the subsequent tinplating is much more uniform and more highly resistant to corrosion. This is an instance in which a higher-quality gas results in a higher-quality product that is more acceptable to the purchasers of the product; for example, food packaged in tin cans is less likely to spoil.

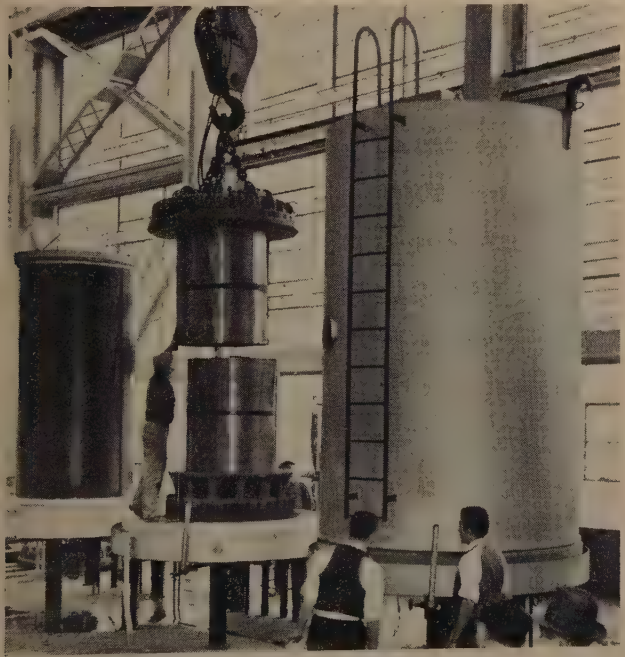

Fig. 117. Bell-type electric furnace for bright-annealing wide coils of low-carbon steel strip. Coils being loaded on supporting pedestal of base (*center*), retort over stack of coils in cooling position (*left*), and bell furnace over retort and stack of coils for heating (*right*)

A typical analysis of the protective atmosphere is 2 percent CO, 2 percent H_2, and 96 percent N_2, with dew point −40 F. As compared with the combusted gas, the absence of carbon dioxide and the very low water-vapor content are considered responsible for the success of this application.

Preparation for Galvanizing

An interesting new application of protective atmospheres is in the continuous annealing of steel strip, and preparation of its surfaces by reduction of oxides, in advance of galvanizing. First, the strip is heated to about 1350 F in a furnace which has a protective atmosphere consisting of a highly reducing mixture of dissociated ammonia (D1 in Table I) and high-ratio Neutralene (E2c); then it enters a cooling chamber having a protective atmosphere of high-ratio Neutralene (E2c) where it is cooled to about 850 F. The strip then passes into an 850 F bath of molten zinc without flux, where it is coated, after which it emerges into the air. Following this, the strip is cooled, sheared, and stacked ready for shipment.

A high-quality product results from this method, inasmuch as adherence of the zinc to the steel is very good, and the coating of zinc is uniform, which results in reduced zinc consumption. Since the operation is also continuous and automatic, it involves a minimum of attention and labor and has an exceptionally short manufacturing cycle. As a result, the highest available quality of product can be obtained, and at an attractively low cost.

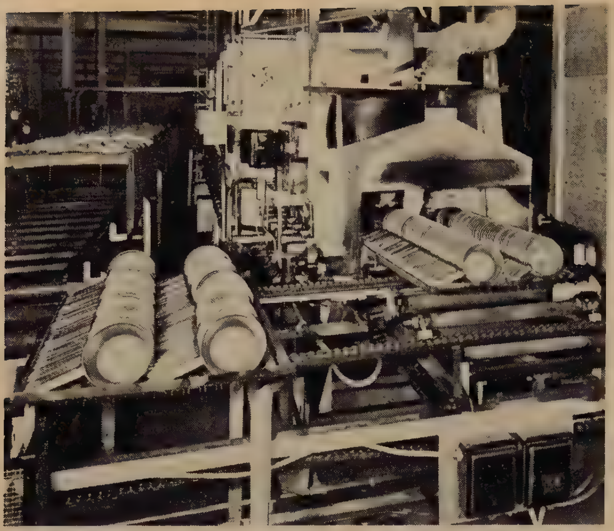

Fig. 119. Trayloads of steel pans ready to enter charging end of roller-hearth controlled-atmosphere electric furnace, to be bright-annealed prior to porcelain-enameling to replace cleaning and pickling operations

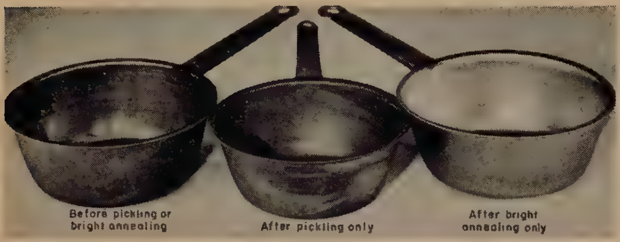
Before pickling or bright annealing
After pickling only
After bright annealing only

Fig. 120. Excellent surface finish obtained by bright-annealing in protective-atmosphere furnace is shown in pan at right, as compared with pickled pan at center. The appearance before bright-annealing or pickling is indicated at the left

The Cover illustration shows an installation that includes two large furnaces for the process described. In the background, near the center of the picture, is a horizontal roller-hearth-type furnace which handles relatively thick strip, ranging from 0.050 to 0.125 in. thick, up to 54 in. wide. In the foreground, at the right, is a tower-type furnace for handling relatively thin strip ranging from 0.012 to 0.040 in. thick, up to 48 in. wide. Each furnace is located in the middle of a processing line, at the beginning of which is an uncoiler, electrolytic cleaner, and various other accessories. Beyond the furnace and galvanizing tank is a cooling tower for cooling the strip after galvanizing and a line of equipment for either coiling the strip or cutting it into sheets.

Low-carbon Coiled Wire

Coiled low-carbon steel wire is annealed in bell-type furnaces which are very similar to those used for steel strip, such as that shown in Fig. 117. A typical load of coils of about 30-in. outside diameter, stacked 5 ft high, weighing about 3000 lb, is heated to 1400 F in 3½ hr, and cooled in 6¼ hr, totalling only 9¾ hr for the entire cycle.

The advantages of annealing coiled wire in the bell-type furnace are generally the same as for strip. Atmospheres, too, are the same, usually being low-ratio combusted gas (E1a).

Bright-annealing Before Porcelain-enameling

A relatively new application of protective atmospheres is in the bright-annealing of ware prior to porcelain-enameling (30) to replace cleaning and pickling operations. Fig. 119 shows a trayload of typical ware (*right*) about to enter the charging end of a roller-hearth electric furnace, and another trayload (*left*) on a transfer table ready to move automatically into charging position, after having been loaded with ware on the return conveyor. Fig. 120 shows the effectiveness of bright annealing in this manner. At the left is a pan before cleaning; in the center, a pan cleaned by the former pickling method; and at the right, a pan which has been bright-annealed in the electric furnace. The latter has a considerably improved appearance over the pickled one and, in fact, is so clean that it resembles aluminum in appearance.

Bright-annealing of the ware offers numerous advantages among which are: Clean neutral surface with no alkali or neutralizer to hold or retard the flow of ground-coat enamel during the dipping operation; reduction of welding and drawing stresses; elimination of pickling blisters, scaling, and other defects attributed to pickling; improved product and product appearance, particularly at the welded joints, because the blue oxide from spot welds disappears completely; reduction of operating personnel; improved working conditions due to elimination of messy pickling rooms; fewer rejects; and lower costs with savings of 25 to 30 percent.

The furnace operates at about 1600 F with low-ratio combusted gas atmosphere (E1a) consisting of about 5 percent CO_2, 10 percent CO, 15 percent H_2, 1.5 percent CH_4, and 68.5 percent N_2. A material handler brings the ware to an operator at the loading position along the return conveyor. Here the pieces are nested or stacked on trays with no special precaution to separate the pans. The trayload is automatically charged into the furnace as shown in Fig. 119; travels through its heating and cooling cycles; and is then automatically discharged, transferred to the return conveyor, and moved along to the operator, who removes the ware and reloads the trays as described. Thus, the operation is completely automatic, and only one operator is required to load and unload the work.

Low-carbon Stampings and Tubing

A variety of parts require annealing operations during fabrication; low-carbon steel stampings, tubes (Fig. 121), machined parts, and similar products made from nonferrous metals are typical. Usually the parts are heated and cooled as quickly as possible in adjoining heating and cooling chambers, such as in a mesh-belt furnace (Fig. 121). Similar short-cycle annealing is also done in box and roller-hearth conveyor-type furnaces, the type generally being determined by the amount of production involved.

Advantages of annealing in this manner include: uniform heating in the electric furnace, resulting in uniform ductility of the parts annealed; bright or relatively clean surfaces of the parts, depending on the type of metal treated, which eliminates or minimizes subsequent cleaning operations; minimum handling of the parts, thus utilizing a small amount of labor; short manufacturing cycle; and low over-all cost.

The furnace operator at the charging end of a mesh-belt furnace, as shown in FIG. 121, lays the parts directly on the mesh-belt conveyor, or loads small parts in pans or baskets and places these carriers on the conveyor. The work travels through a gas-flame curtain which minimizes infiltration of air, and slowly proceeds through the heating and cooling chambers in the protective atmosphere. The work emerges at the opposite end through different types of curtains, such as gas flame, asbestos, or fiberglass, depending on the requirements. The parts are usually dumped into a tote box, which is removed periodically, but in some instances the work is lifted off the belt and placed in the tote box. Products such as steel, copper, sterling silver, and nickel silver come from the furnace shiny bright, whereas brass may have a slight zinc discoloration on its surfaces. Combusted fuel gas is commonly used for atmospheres on such applications; partially burned (E1a in Table I) for steel, sterling silver, and nickel silver; and completely burned (E1b) for copper or brass.

Magnetic Iron for Electrical Machinery

The magnetic irons used for electrical machinery vary from plain low-carbon to high-silicon-alloy low-carbon iron. The exact analysis, rolling procedure, and heat treatment vary with the type of iron and the type of electrical machinery for which it is intended.(6) For many years certain grades of both nonsilicon- and silicon-type irons have been produced in sheets which are annealed after rolling. Sometimes when the sheets are punched into laminations for motors and generators, an annealing operation follows the punching operation to eliminate punching strains and reduce electrical losses.

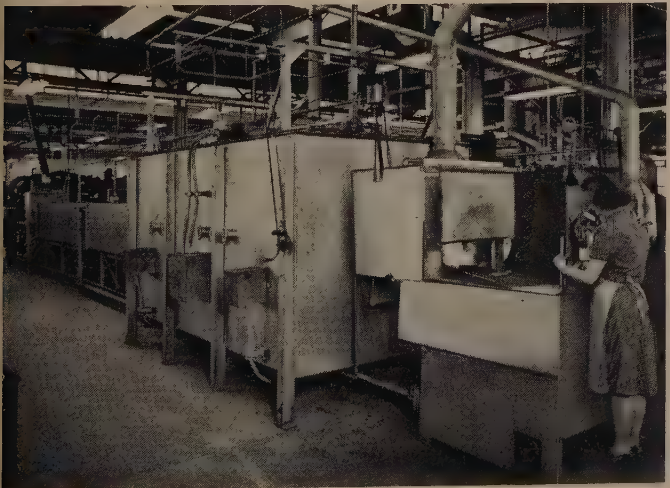

Fig. 121. Furnace operator loading cut-steel tubes onto conveyor of controlled-atmosphere mesh-belt electric furnace, for bright-annealing. Heating chamber is at center, cooling chamber at left

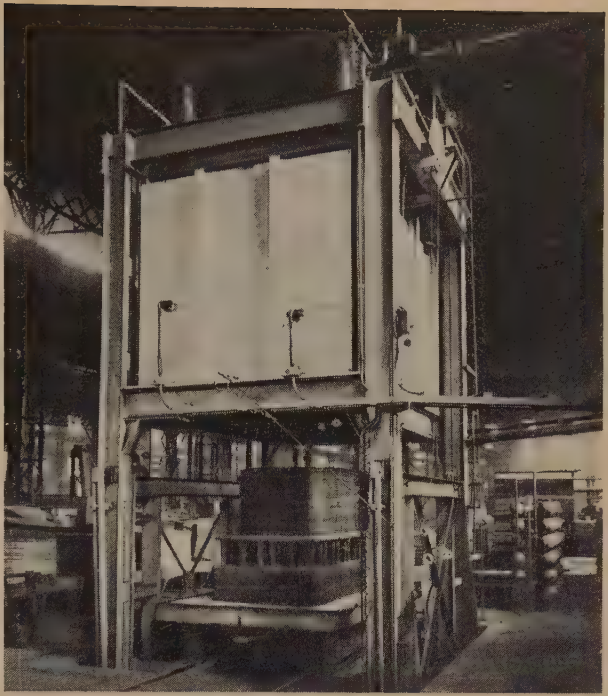

Fig. 122. Stack of silicon-iron sheets ready to be lifted upon car-type base into elevator-type electric annealing furnace with protective atmosphere

Sheets and Punchings. Elevator-type furnaces, similar to that shown in FIG. 122, are one of the earlier types used for the annealing of sheets and punchings. In such furnaces, one type of protective atmosphere used consists of about 15 percent hydrogen and 85 percent nitrogen. Some of the irons can be annealed at low temperatures with combusted gas; but the particular type of atmosphere depends on the type of iron, the temperature involved, and results desired.

Usually a protective atmosphere is used, first, to reduce oxidation of the iron, since this oxide would be detrimental in subsequent stacking of the sheets, and it may cause the sheets to tend to stick together after the annealing. Sometimes the atmosphere is used in an attempt to remove traces of carbon which remain in the iron, for lowest electrical losses depend on having the carbon content very low. In still other instances, the atmosphere serves not only to prevent normal oxidation of the sheets but also to prevent loss of silicon due to oxidation, the presence of which is essential in certain types of irons to keep the electrical losses at a minimum. If the silicon is removed by oxidation, the iron will then lose its desirable electrical properties.

Continuous Strip. For a number of years, manufacturers have been using silicon-iron strip with which to wind spiral-core transformers. It was found that continuous annealing of the strip permits control over the grain structure, resulting in improved magnetic and electrical qualities of the iron. Such strip is annealed in a catenary furnace, similar to that shown in Fig. 123. In this furnace the strip is supported in the heating chamber in the form of a catenary, by means of rolls so located that the strip does not touch any rolls within the high temperature zone. The strip passes from the heating chamber to the cooling chamber where it is cooled to a sufficiently low temperature so that it will not oxidize to an undesirable degree in the air. In furnaces of this type, high-ratio combusted gas (E1b) is frequently utilized although, if the iron should require it, a higher-hydrogen type of gas may also be used.

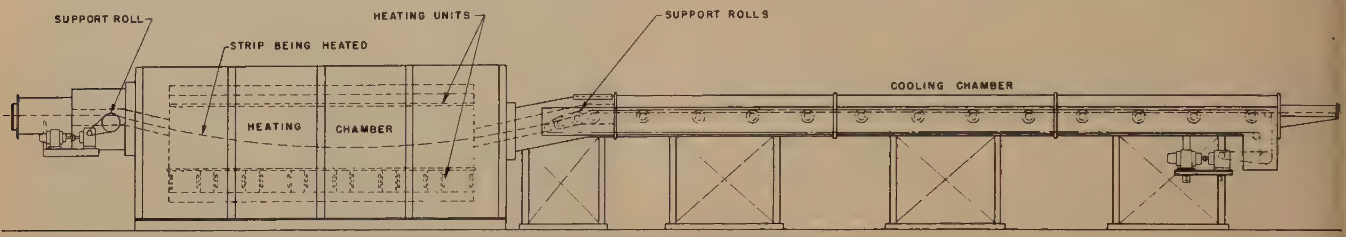

Fig. 123. This catenary electric furnace for continuously annealing silicon-iron strip has rolls only in the cooled zones to minimize scratching of the strip. Accurate temperature control and protective atmosphere contribute to high quality

Coiled Strip. A recent development is the annealing of coils of high-silicon iron strip, rolled to have an oriented grain. Irons of this type must be batch-annealed, since slow heating and long holding time at temperature, and also relatively slow cooling, is required to obtain the preferred orientation of grains.

During this annealing operation, the iron must be protected by purified dry hydrogen (A2 in Table I) to prevent oxidation and removal of silicon from the iron. The purification and drying of the hydrogen is done to remove all traces of oxygen and water vapor which, at the high annealing temperature of about 2100 F, would oxidize the silicon and thereby remove it from the iron.

Annealing of this type of iron is normally carried out in elevator-type furnaces of the type shown in Fig. 124. The coils of silicon iron are placed in welded steel containers which, in turn, rest upon the car-type base of the furnace. The containers are purged of air by passing nitrogen through them. When all air has been removed, the nitrogen is purged from the boxes by means of purified dry hydrogen. After such purging, the charge is placed into the furnace which is at a temperature of around 1500 F. The furnace temperature is then increased over a period of hours to about 2100 F, after which the steel is held for a number of hours, depending on the results desired; then it is slowly cooled to about 1500 F, and the charge is removed from the furnace with the iron still protected in the boxes by purified dry hydrogen.

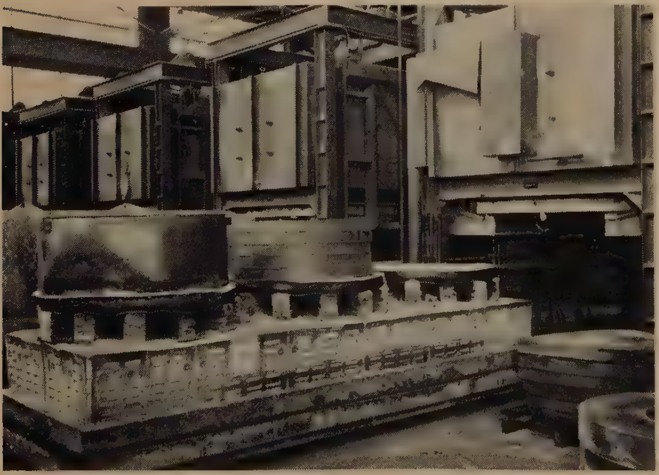

Fig. 124. Coils of high silicon-iron strip (*center*) are annealed in purified dry hydrogen in retorts (*left*) in a battery of elevator-type electric furnaces shown in background

The treatment in purified dry hydrogen provides the highest quality of magnetic iron available today. It is gradually being adopted by most electrical manufacturers for their highest-quality products, such as turbine-generators, motors, and transformers.

Small Motor Parts. Miscellaneous small motor parts, cast-iron brake shoes, and transformer iron are annealed in the roller-hearth electric furnace shown in Fig. 125. Typical production is laminations of low-carbon silicon iron approximately 0.030 in. thick, ranging from 2½ to 30 in. in diameter. The laminations are first heated to 750 F in a burnoff chamber with air atmosphere to remove the lubricating oil applied in the stamping operation. They are then heated to 1600 F in the main heating chamber in low-ratio combusted gas (E1a) with an analysis of about 5 percent CO_2, 10 percent CO, 15 percent H_2, 1.5 percent CH_4, and 68.5 percent N_2. The laminations are then cooled in the protective atmosphere at a controlled rate to 1000 F, followed by accelerated cooling to 150–200 F by means of high-velocity air which is drawn through and around the stacks of laminations. Action of the air on the iron at 1000 F and below causes it to be slightly oxidized or blued which thus produces a desirable rust-inhibiting surface.

Numerous benefits have been obtained by annealing the parts in this manner to obtain low-residual magnetic properties. These include uniformity of the iron due to the uniform heating, accurate temperature control, and uniform controlled cooling; uniform surfaces of parts due to the protective atmosphere; short manu-

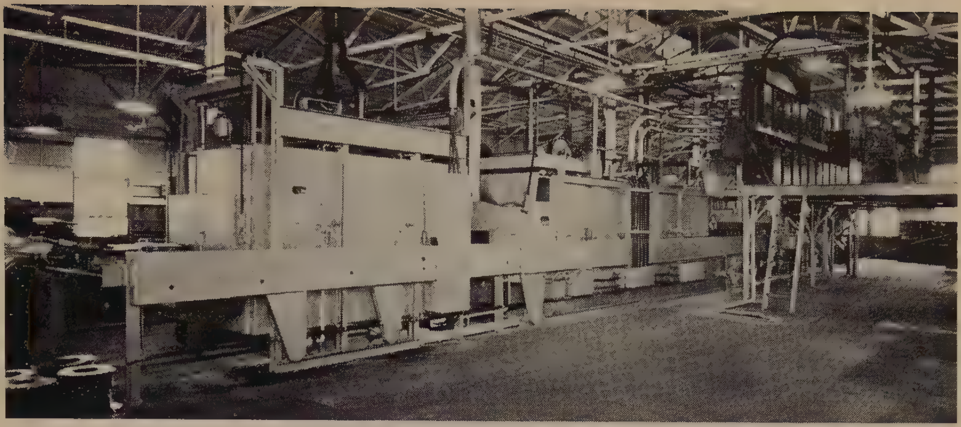

Fig. 125. Small motor parts, cast-iron brake shoes, and transformer iron are annealed in protective atmosphere in this roller-hearth electric furnace. Burn-off chamber (*left*) heating chamber (*center*) and cooling chamber (*right*)

facturing cycle due to minimum heating-and-cooling rate; and low annealing cost due to good operating economy, negligible maintenance, and minimum labor with only one operator required.

A typical trayload of parts includes 550 lb net of iron, the tray itself weighing 60 lb. The trays, made of heat-resisting alloy channels, are about 36 in. square. The required number of laminations for one motor are stacked and held together with two wires which are subsequently removed. With trays automatically entering and leaving the furnace about every 18 min, production of annealed laminations is about 1900 lb net per hour. The burnoff chamber is about 7 ft long, the high-heat chamber 15 ft long, the controlled-cooling chamber 10 ft long, and the fast-cooling chamber 18 ft long.

Stainless Steel

Lightly Oxidized. Stainless-steel stampings do not lend themselves to bright-annealing technique, except on applications where high cost is permissible in providing and maintaining a high-purity protective atmosphere. Large-scale production annealing of stainless-steel stampings is more commonly performed in batch- or continuous-type controlled-atmosphere furnaces, in which light oxides form and are subsequently removed by pickling or sodium-hydride descaling.

A typical example in the annealing of Type 302 stainless steel(31) involves the use of a roller-hearth conveyor-type furnace for annealing drawn shells. A common size is 6 in. diameter by 9 in. high, although other sizes are also treated. After heating to 1850–1900 F, the work is quickly cooled in a primary cooling chamber to 800 F, then slow-cooled in a secondary cooling chamber. The over-all heating-and-cooling cycle is illustrated in Fig. 126.

Advantages of the protective-atmosphere electric annealing furnace over those of an oil-fired furnace previously utilized include more uniform heating, which not only improves the subsequent drawing properties but gives a more uniform scale. The latter results in additional direct benefits, such as shorter pickling time, reduction in number of rejections due to over-pickling, less scrubbing after rinsing, and higher-quality surface finish. Estimates of cost savings per 100 shells, comparing the former batch method with the present continuous protective-atmosphere furnace method, include a 40¢ saving for annealing and a 45¢ saving for pickling, on a typical size shell. The over-all time in this furnace has been reduced from about 40 min, including 20 min heating and 20 min cooling, to about 30 min, including 15 min heating and 15 min cooling. The average pickling time of 30 min for the former method has been reduced to about 12 min for the present method.

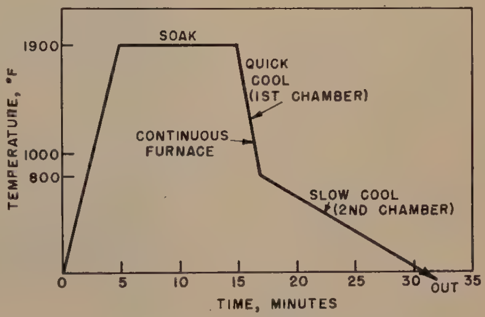

Fig. 126. Typical heating-and-cooling cycle for 18-8 stainless steel annealed in the roller-hearth furnace. Note quick cooling after thorough soak, followed by slow cooling in lower range

The protective atmosphere used in the installation cited is low-ratio combusted gas, consisting of about 18 percent H_2, 11 percent CO, 4 percent CO_2, 1 percent hydrocarbons, the remainder being nitrogen and water vapor. The scale produced on the 18–8 stainless steel in this atmosphere is a sooty black, which easily can be partially rubbed off with a rag, and the remainder easily pickled off. After pickling, the surfaces have a semi-matte silvery finish, which is uniform and conducive to polishing whenever this operation is required.

Bright. Stainless steel in strands, such as wire or strip, can be bright-annealed so that subsequent pickling is not required.(6)(32) In the pickling to remove light oxides, the bright lustrous finish is damaged and can be restored only by drawing or rolling, which would again work-harden the material and would be objectionable. For example, the extra hardness causes undue wear on forming dies for automobile trim, which often must receive rather drastic forming.

Bright-strand-annealing of stainless steel is done by passing the product through tightly sealed alloy retorts

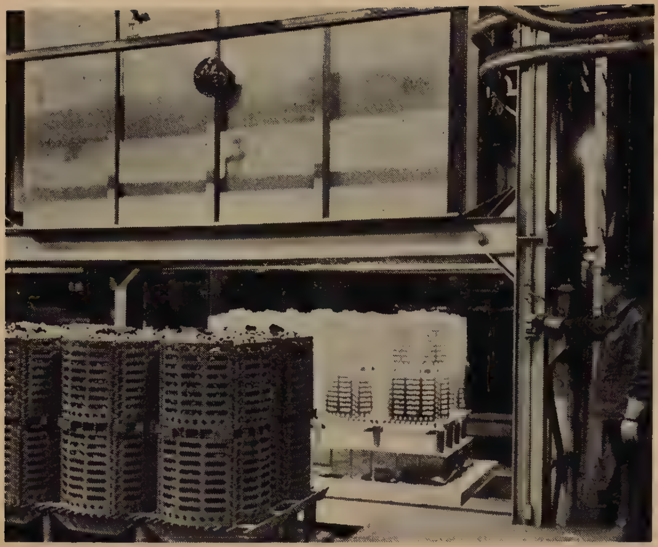

Fig. 127. Annealing malleable-iron castings in elevator-type electric furnace, in which carbon monoxide driven off from the castings during the heating cycle serves as the protective atmosphere. Heated charge is shown being transferred from high-temperature furnace in foreground to low-temperature furnace obscured in background

throughout the heating and cooling chambers of a furnace. The protective atmosphere is usually pure dry hydrogen (A 2 in Table I) or dissociated ammonia (D1) the latter usually being passed through an activated alumina dryer to obtain highest purity. By annealing in this manner, not only is a gas of exceptional purity utilized but great care is taken to prevent infiltration of air or water vapor by means of the alloy retort. In annealing 18–8 or 17 Cr-iron stainless at about 1400 F with proper conditions, the bright surface on wire or strip can be retained.

Medium- and High-carbon Products

Coiled strip and wire of medium- and high-carbon content are commonly annealed in bell-type furnaces, similar to those used for low-carbon products⁽⁶⁾, such as shown in Fig. 117. The main differences are that the brickwork of the base is covered by metal for the high-carbon products but it is left uncovered for the low-carbon ones, and the sealing liquid is oil instead of water. The object of covering the base is to prevent moisture and oxygen in the brickwork from contaminating the nondecarburizing atmosphere used, and the oil prevents the gas from absorbing moisture from the seal. Atmospheres commonly employed for the medium- and high-carbon steels in bell-type furnaces are dissociated ammonia (D1) and high-ratio Neutralene (E2b). Low-ratio Neutralene is not recommended for long-batch anneals because the high CO content results in soot deposit on the work and possible etching of the surfaces, because of the long time available for reactions at relatively low temperatures. This effect does not occur in short-cycle annealing, and the high CO gas is then desirable because of its high carbon potential.

Malleable-iron Castings

Tightly sealed modern electric furnaces for annealing malleable iron castings, such as illustrated in Figs. 127 and 128, require no auxiliary source of protective atmosphere. Carbon monoxide is driven off from the castings during the annealing cycle at elevated temperatures, which serves as the protective atmosphere and the castings come from the furnaces free of any scale and decarburization. Many fuel-fired furnaces are not tightly constructed, however, and it has been found that the use of Neutralene (E2c in Table I) is useful in them to prevent air infiltration and to regulate the amount of CO present, thus eliminating both oxidation and decarburization.

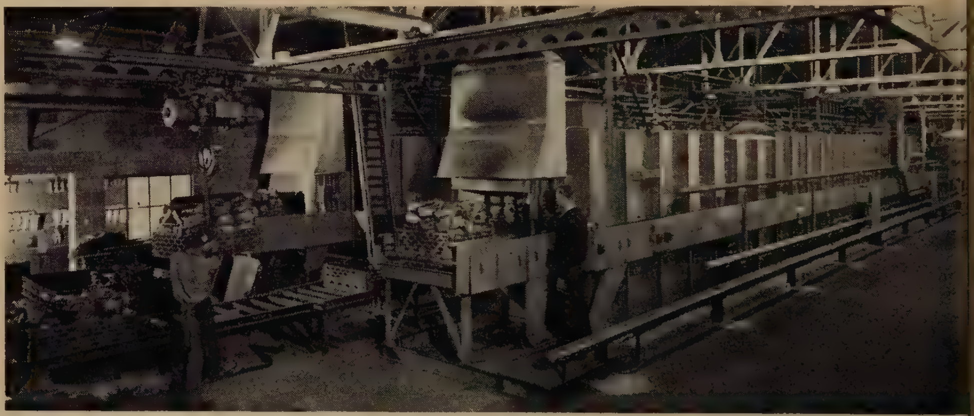

Fig. 128. Trayloads of malleable-iron castings being annealed in two roller-hearth electric furnaces, in which carbon monoxide driven from the work serves as protective atmosphere

Advantages of modern electric furnaces for malleable-iron annealing⁽³³⁾ over old fuel-fired periodic furnaces include lower cost of energy; less maintenance, labor, and floor space; shorter time cycle; and better working conditions. Of particular importance is the higher quality made possible by the use of electric-furnace annealing equipment, because of the accurate control of temperature, uniform temperature distribution, and the definite control of the time cycle. Also, because of the clean scale-free surfaces, further savings in subsequent operations are made by the uniform anneal and elimination of cleaning, often with lower cost of machining.

The annealing cycle depends on the type of iron being treated and its analysis. A typical time-temperature curve is shown in FIG. 129. The time represented by *A* is that required for heating the castings to temperature. This time depends on the size and type of furnace. Period *B* depends on the analysis of the iron and results desired. This time for holding at temperature may be anywhere from 5 to 25 hr. The higher the silicon content, the shorter this holding time will be. The fast-cooling as represented by *C* may be as rapid as furnace conditions permit. The slow-cooling portion of cycle *D* also depends on analysis of the iron and the physical properties desired. This may be anywhere from 5 to 24 hr. Typical analyses of malleable iron vary in silicon content from 1 to 1.6 percent, carbon from 2.2 to 2.6 percent, and manganese from 0.30 to 0.45 percent.

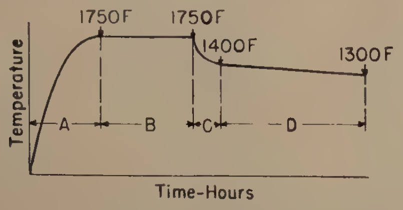

Fig. 129. Typical time-temperature curve for annealing malleable-iron castings

A: Heating-up period
B: Soaking period
C: Fast-cooling period
D: Slow-cooling period

Electric malleable-annealing furnaces are provided in four types: Elevator, rectangular-bell, continuous roller-hearth, and continuous pusher-tray type. The selection of the type and size depends on the rate of production and the annealing cycle required. Where production is high, a continuous furnace may be considered; for most foundries, however, the elevator furnace is the type commonly utilized.

The two portions of the annealing cycle—that is, the high- and the low-temperature portions—are about equal in time. Thus, where the elevator furnace is used, two furnaces are installed for carrying out the complete cycle: one for the high-temperature portion and the other for the low-temperature. FIG. 127 shows a load of castings which has just been lowered out of a high-temperature elevator furnace, and which is about to be transferred to a low-temperature elevator furnace in the background. A cold load at the left is ready to enter the high-temperature furnace.

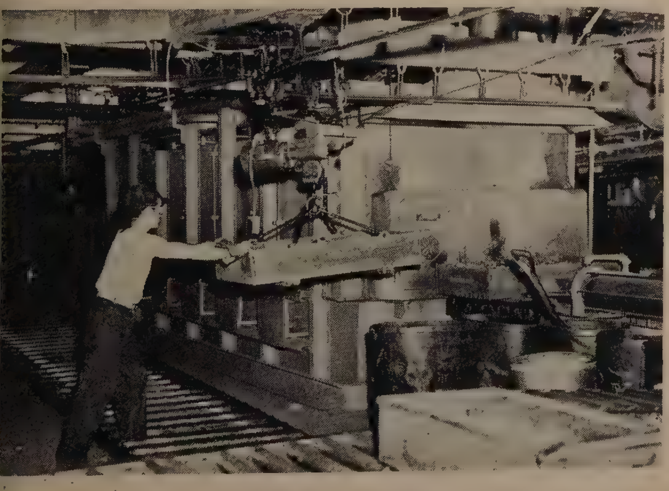

Fig. 130. Trayloads of small gray-iron castings being clean-annealed in pusher-type electric furnace with protective atmosphere. One trayload is in position in front of charging door (*right*), another trayload is ready to take its place (*center*)

When a continuous furnace is desired, the choice is between a roller-hearth or pusher-tray type. The roller-hearth has the advantage of less maintenance as well as being readily cleared when production stops. FIG. 128 shows an installation of two electrically heated roller-hearth furnaces, each rated 700 kw, having an over-all length of 138 ft. The charging table is shown at the left with loaded tray in position. The tray is automatically charged into the furnace chamber where it is carried by the motor-driven roll table continuously through the high-temperature section, the fast-cool section, and the slow-cool section. Then the tray is automatically discharged from the furnace. Thus, the entire cycle is under complete automatic control.

Clean-annealing Small Gray-iron Castings

An electric pusher-type furnace with protective atmosphere, FIG. 130, is typical of similar equipment used to clean-anneal small gray-iron castings. The furnace shown is one of two which were installed to replace an old muffle-type fuel-fired furnace, in which the work was charged in cast-iron boxes with covers and manually pushed through the furnace. The castings vary in size from ¼ to 12 lb, the longest one being 16 in. in length and the thickest one 3 in. in diameter.

With the castings loaded openly in the trays, as shown in FIG. 130, the time cycle has been considerably shortened, it formerly being 8 hr heating and 8 hr cooling, and now being about 2½ hr heating and 2½ hr cooling. Other advantages are: Better uniformity of anneal, resulting in lower machining cost; elimination of expensive scale-removal operations; elimination of fuel-handling and fuel inventory; improved carriers (trays) of lighter weight, with less heat absorption, longer life, and greater ease of handling; reduced operating personnel, due to automatic temperature control and work-handling through the furnace; reduced maintenance; improved working conditions; and lower costs.

The furnace operates at 1450–1500 F, with low-ratio combusted gas having analysis of about 5 percent CO_2, 8 percent CO, 13 percent H_2, 1 percent CH_4, and 73 percent N_2. Each tray holds up to about 400 lb of castings, loading about 125 lb per cu ft. A loaded tray is placed in position in front of a pusher mechanism, shown in FIG. 130, the door automatically opens, and the tray is pushed into the furnace by an automatically timed hydraulic cylinder, moving all trays one tray length throughout the furnace. After the charging door is closed, the discharging door opens, and a tray is run out by motor-operated rolls and deposited on a transfer table. The discharge door closes automatically, and the motor-operated rolls stop. In the meantime, a transfer table carries the tray to the top of a gravity-roller conveyor, located between the two furnaces, where another pusher starts the tray down the return conveyor, which carries it to the front of the furnace for unloading and reloading.

Copper Wire

Copper wire in coils, or wound on spools or reels, is commonly bright-annealed in bell-type furnaces such as that shown in FIG. 131. The protective atmosphere is usually high-ratio combusted gas with sulphur removed, with an analysis of about 11.5 percent CO_2, 0.5 percent CO, 0.5 percent H_2, and 87.5 percent N_2.

Advantages from annealing copper wire in a cylindrical electric bell-type furnace are: uniformly bright wire resulting from accurate control of furnace atmosphere; minimum gas consumption for atmosphere, due to liquid seal; high production per unit floor space; uniformly ductile wire due to even heat distribution throughout the load; low operating costs; low maintenance costs; portability of equipment; flexibility, in that different time-temperature cycles can be used on each load, if desired; and good working conditions due to minimum heat loss. The operating economy is good either under peak- or low-production conditions.

The work is stacked on a loading pedestal, as shown at the left in FIG. 131, and covered with a sheet-metal retort which engages with a liquid seal around the bas
A protective atmosphere surrounds the work withi
this retort throughout the heating-and-cooling cycl
A bell-type furnace is lowered over the retort for th
heating cycle, and lifted off for the cooling cycle an
put over another load on a different base. Thus, whi
one load is heating, several loads are cooling and another base is being unloaded and reloaded. A typica
equipment consists of a furnace with three or four base
and retorts. A normal load in the furnace shown consists of about 2500 lb of copper in coils, but the load i
others varies from 1000 to 20,000 lb of copper. The be

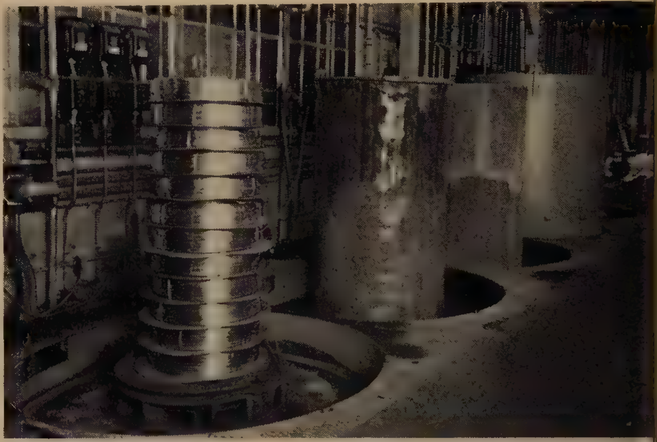

Fig. 131. Stack of copper wire in coils on loading pedestal over cooling g
fan (*left*) ready to be bright-annealed under retort (*center*), in bell-type
furnace (*right*). Protective atmosphere within the retorts throughout t
heating-and-cooling cycles assures bright finish on wire

furnace held at about 500–1000 F (depending on siz
of wire) rests over a load about 1½ to 3 hr before it i
lifted off. Cooling of the work is accelerated by us
of a water spray on the outside of the retort, as show
at the center of FIG. 131. The load cools to a nonoxidizin
temperature in approximately twice the heating time
at the end of which time the retort is lifted off to complete the cycle.

Fans in the load-supporting bases circulate the gas
This accelerates the heating-and-cooling cycle an
contributes to the good uniformity of heating throughout the charge. When the load consists of spools,
cylindrical shield is placed over it to assure that th
circulated atmosphere will travel to the top of th
retort and back down through the charge, to preven
short-circuiting of the gas flow, thus heating the charg
uniformly throughout its height.

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(To be continued)

NEW
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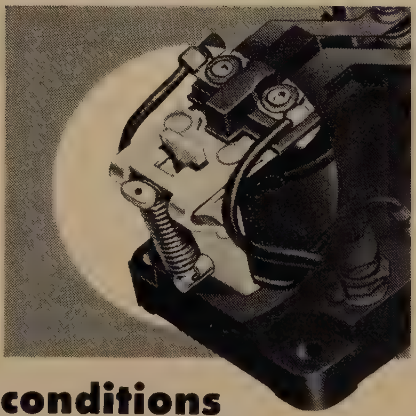

Ward Leonard's new Bulletin 110 Relays have unusually heavy contact pressures . . . good proportioning of contact masses and springing . . . and semi-knife-edge bearings assuring long trouble-free service under adverse conditions.

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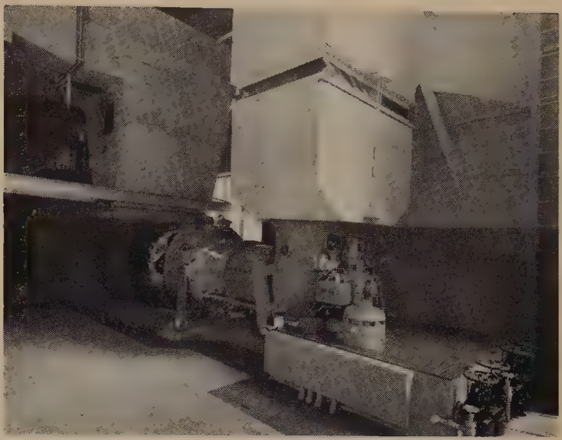
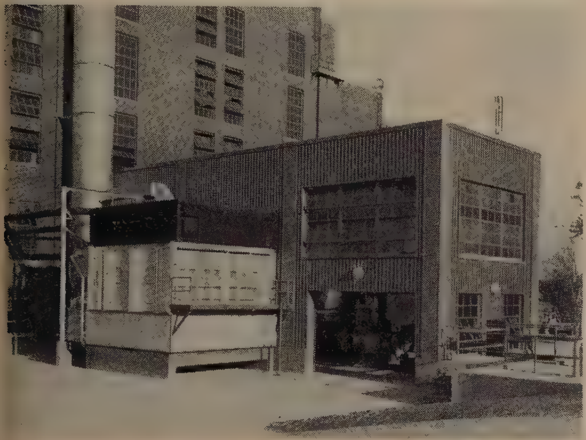
HIGH LIGHTS AND SIDE LIGHTS

Gas Turbine for Central Station

The first public showing of a central-station installation of the gas turbine, held recently in Oklahoma City, marked the successful beginning of a new chapter in power generation in the United States. The 3500-kw simple-cycle gas-turbine power plant was installed at the Arthur S. Huey Station of the Oklahoma Gas and Electric Company.


Interior view from the compressor end, showing air intake, gas turbine, exhaust to the heat exchanger, and in the rear the load end of the gas-turbine power plant


The small size of the gas-turbine building contrasted to the over-all size of the plant in the background indicates the economy in installation

In more than 1500 operating hours, the gas turbine produced approximately 5¼ million kw-hr at an average of 3557 kw. In one day's operation, the gas turbine permitted a pickup in total station output from approximately 51,000 kw to 58,000 kw, with an over-all improvement in plant operating economy. Of this pickup the gas turbine carried approximately 4000 kw; the balance of 3000 kw was achieved in plant operation. The gas turbine carried as much as 4300 kw during this time.

This gas-turbine power plant represents the first commercial application in this country, for central-station use, of the design principles first used in the aircraft jet engine; it is much like the 4800-hp locomotive gas turbine now in regular freight service, as part of its road tests, in California.

The new gas-fired unit is installed in a building, of less expensive construction, added to one side of the existing plant. The building has a standard crane and power hoist operated from the floor. A large door allows trucking or dollying any part of the equipment into the main-plant machine shop.

The weight of the complete power plant, including the compressor and gas turbine unit, is only 25,000 lb. The complete unit, including the generator and exciter, is less than 50 ft long and 9 ft wide and, with the exception of the oil tank, is located on one floor level. The design of the gas-turbine power plant, which eliminates the need of much of the bulky equipment demanded by steam-generating units, makes it especially desirable for adding capacity to existing stations.

Operating on natural gas, which is abundant in the area, the turbine makes available more total power than that which it generates itself. The waste heat from the exhaust is used with a separate heat exchanger to supplement the present feed-water heating system. By supplementing the heating capacity of the installed equipment, better utilization is made of the available turbine-shaft capacity of the steam-generating units.

Studying Rust Through Radioactivity

Radioactivity has provided a means by which science may learn to control common rust.

In experiments using radioactive tracers, engineers have devised a method revealing photographically how rust starts, where it starts, and how deep it goes.

Radioactive tracers are particularly suitable for rust experiments because radioactivity is not affected by the chemical change which results in rust.

For this purpose, a solution holding radioactive iron is electroplated onto the surface of the metal to be studied. A photographic plate is then placed against this surface and left for several days. During that time, an x-ray exposure is made on the plate by the radioactive coating. As the test metal rusts, a decrease in radiation results, showing up graphically as lighter areas on the photographic plate.

By taking a series of these autoradiographs, the engineers can see photographically the nature of the rust forming on the test metal.

The rusting of a wide variety of metals can be studied by applying different, selected radioactive isotopes.

New Steel Mill Uses Power Rectifiers

Electric drive and control equipment is now being built for the West Coast's first semicontinuous hot-strip steel mill.

Eighty-six inches wide and capable of rolling sheet steel at 1500 feet per minute, the new mill will be added to an existing roughing mill at a California plant. Steel slabs, broken down on the roughing mill, will be finished into wide strip and sheet steel on the hot-strip mill. Power will be supplied by three 5000-hp and one 3500-hp motors. The equipment includes also auxiliary motors, control equipment, switchgear, transformers, and ventilating equipment.

This will be the first hot-strip steel mill in the country to use rectifiers alone for converting the alternating current supplied to the mill to the direct current required by the drive motors. Previously, mills of this type used separate motors and generators for the conversion.

When the new mill is completed, it will be used to produce steel for welded pipe and for other products requiring heavy-gage sheet steel.

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Planer and Milling Machine For the Big Jobs

A gigantic planer and milling machine that can shave as little as 1/1000 of an inch from a steel block the size of a railroad boxcar has been placed in operation to facilitate the manufacture of large equipment for industrial and power generating applications, such as synchronous condensers, hydraulic-turbine-driven generators, and large steel-mill motors and generators.

The giant table will carry up to 200 tons for either planing or milling

The machine has a 27-ft-high arch; its sliding table is 40 ft long. Capable of functioning as either a planer or a milling machine, it eliminates the task of transferring materials to two machines when both operations are required. The table will carry loads up to 200 tons and, because of its great size, will permit several large parts to be bolted to it and machined as a single unit.

Enough concrete to lay a sidewalk more than 2½ miles long and 30,000 lb of steel were required for the foundation.

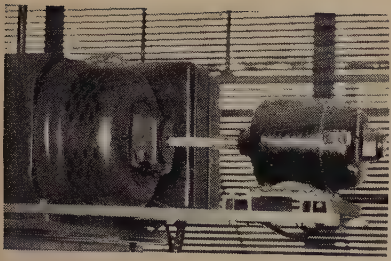
From two pendant push-button stations, the machine is completely controlled by electronic equipment. These stations, one for each operation, hang from the top of the arch and can be readily carried to different locations, enabling the operator to control the machine from the most advantageous position.

An emergency lever, which responds to a slight touch of a finger, protrudes from the bottom of the pendant station and, when touched, stops the machine at once.

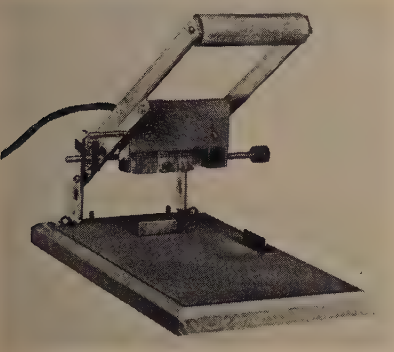
A single switch converts the machine to either the planing or the milling operation. When it performs as a planer, a 100-hp motor moves the table at speeds ranging from 10 to 150 ft per minute.

During the milling operation, the table travels from 3 to 45 inches a minute while two 50-hp motors operate the cutters.

NEW PRODUCTS: AND WHAT THEIR MAKERS HAVE TO SAY ABOUT THEM



D-c Tachometer Generator



Stamping Press

Stamping Press

The Wynnliner simplified easy-to-operate electrically heated stamping press designed for the electrical equipment trade. Because the press with its easily adjusted guides prints objects paper thin or up to 2 in. in thickness, it can be used for printing a variety of items, such as name plates and advertising messages on plastic or wooden handles, with emphasis on product identification. The press imprints in gold, silver, or colors single lines up to 3 in. in length. It takes up to 36-point type of any standard make, and prints from changeable type, dies, and linotype. It consumes only 30 watts of 110 volt a-c or d-c, and prints from foil.—*Wynn Manufacturing Co., Philadelphia, Pa.*

Gas Purifiers

Three new Deoxo purifiers supplement Model P which provides for the catalytic combination of oxygen and hydrogen in the presence of carbon monoxide.

The first of these instruments, Model M, provides for the catalytic combination of oxygen and carbon monoxide to form carbon dioxide in gases that do not contain hydrogen; for the catalytic oxidation of hydrogen in oxygen gas; and of carbon monoxide to carbon dioxide in hydrogen-rich atmosphere, if gas is maintained between 120 and 160 C.

Model DM purifier provides a simultaneous catalytic combination of carbon monoxide plus hydrogen to carbon dioxide plus water vapor, with temperature maintained between 120 and 500 C. An oxygen content of at least one half the sum of carbon monoxide and hydrogen must be present.

Methane and water vapor are formed from the catalytic combination of carbon monoxide and hydrogen, using Model E purifier. For a complete reaction, gas temperature must be maintained above 200 C. Size of these purifiers range from 200 to 100,000 cfh.—*Baker and Co., Inc., East Newark, N. J.*

D-c Tachometer Generator

A redesigned heavy-duty d-c tachometer generator available in three models for accurate speed measurement of steel- and aluminum-mill machinery, mine hoists, crushing and shipboard equipments, wire-forming machines, paper-mill drives, etc. The generator is totally enclosed and features rubber-mounted ball bearings and an alnico permanent-magnet field (no separate excitation is required). The end play has been preloaded to 100 lb to counteract the end thrust of the large machines to which this sturdy unit is to be mounted. Output voltage of the generator is directly proportional to speed. Sufficient power is produced for (1) control purposes and operation of an instrument simultaneously, or (2) operation of several instruments in parallel. Clockwise and counterclockwise rotation can be indicated by a zero-center instrument.

A speed-volt curve is taken of each new generator and a copy is kept on file. This curve can be used in selecting or calibrating additional instruments without using the generator.—*Apparatus Dept., General Electric Co., Schenectady 5, N. Y.*

Ultrasonic Analyzer

A new system effecting a change in the technique of ultrasonic spectrum analysis is made possible by the Model SB-7 ultrasonic analyzer. The device reduces the analysis of ultrasonics to the simplest, fastest, and most direct procedures by enabling observation of the frequency and amplitude of one or many ultrasonic signals at one time. Indications are obtainable for signals between 2 kc and 300 kc in the form of vertical deflections distributed across a cathode-ray tube screen, calibrated horizontally in frequency and vertically in amplitude to provide direct readings of these values. Typical uses include analysis of ultrasonic vibrations, monitoring telemetering subcarriers and communications carrier systems, evaluating harmonic and intermodulation distortion, etc.—*Panoramic Radio Products, Inc., 10 South Second Ave., Mount Vernon, N. Y.*

Arrester and Cutout Unit

A new unit-combination arrester and cutout combines the basic design features of the 9-kv Hi-stroke arrester and the 7.8-kv 50-amp flip-open cutout, and provides low-cost protection of conventional distribution transformers on rural lines rated 7200/12470 and 7620/13200-volts grounded Y. Various types of mounting brackets are available.

Advantages of the arrester include: low sparkover voltage, high discharge current capacity, exclusive built-in reserve of gas-evolving material to compensate for erosion. Construction of the cutout permits a fuse link to be inserted in the wedge-type contacts from either side, while helical-wound springs retard side sway of contact arm and protect the link from vibration stresses.—*Apparatus Dept., General Electric Co., Schenectady 5, N. Y.*

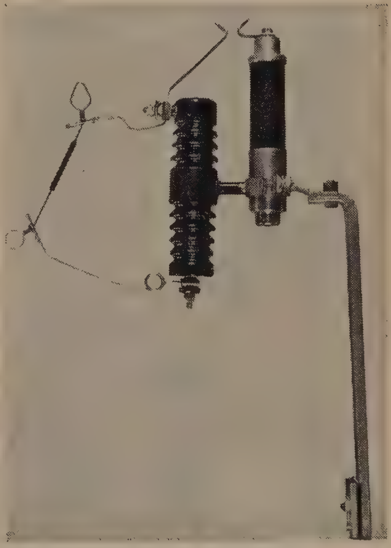
Cemented Carbide

An improved No. 905 grade of cemented carbide for finishing and light roughing cuts on nonferrous metals and cast irons with hardness up to Brinell 550. Higher hardness, more wear resistance, greater cutting-edge strength and cratering resistance, and a more rapid dissipation of heat at the cutting edge are some of the qualities of the improved product. Tools tipped with the material show an even longer service life and do a better job of holding size on long cuts and high production jobs than tools tipped with the former No. 905. The new material is also fully as easy to braze and grind.—*Carboloy Co., Inc., Detroit, Mich.*

Sprockets

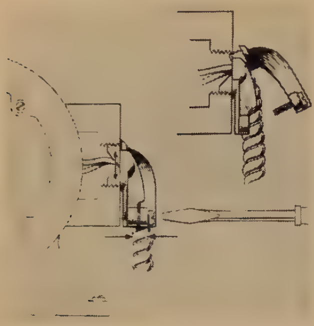
A new line of DH (demountable hub) roller-chain sprockets in a pitch range from ½ through 1¾ in. Practically any speed ratio desired can be obtained from the sprockets. The wheel is made of a steel-plate sprocket, bored and drilled, to which a machined cast-iron hub is attached by heat-treated cap screws. Bolt holes in both plate sprocket and hub are jig-drilled to permit interchangeability. Plate sprockets can be replaced on the hub without removing the hub from the shaft. Larger or smaller plates can be used on the same hub to give seasonal speed changes, and for replacement purposes.—*Fort Worth Steel and Machinery Co., 3600 McCart St., Fort Worth, Texas.*

Sprockets



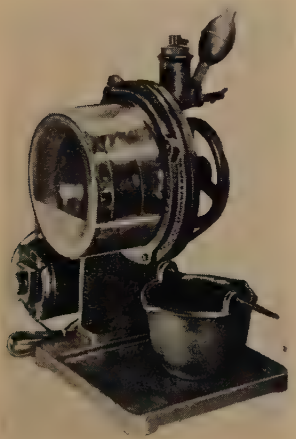
Arrester and Cutout Unit

Cable Connectors



A new threaded-type 90-deg Harbot 238T connector for ⅜-in. armored electrical cable. Made of aluminum die-cast alloy, the connector uses a cam-wedge principle assuring positive grounding and positioning, even when subjected to severe vibration. These connectors are installed after wiring is completed, and it is unnecessary to first screw in the completed part. The simplicity of installing these connectors saves time and labor—a screwdriver is the only tool required.—*Unimatic Corp., 52 East Centre St., Nutley, N. J.*

Purifier



Mercury Oxifier, a motor-driven apparatus for purifying contaminated mercury. Batches of up to 25 lb require almost no attention to transform badly fouled mercury into a product suitable for exacting use. Oxidation of the impurities is done by air. To accomplish this, the mercury is violently agitated in a manner to produce a thick spray in the air space of the glass barrel. Air is also carried down into the body of the mercury, and the skin formations are repeatedly broken up, to release microscopic particles of mercury which they entrap. Upon treatment in this purifier, the mercury is made suitable for use in McLeod gages, manometers, displacement devices, and wherever high purity is desirable.—*Andrew Technical Service, 4747 N. Damen Ave., Chicago 25, Ill.*

Wire

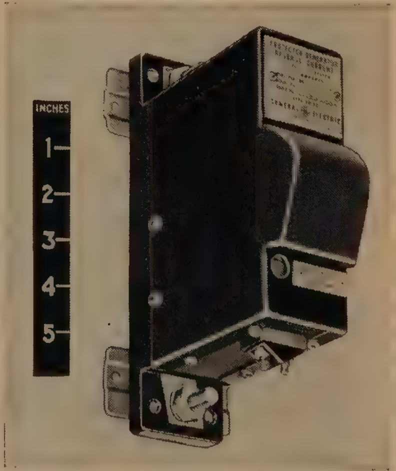
Magic wire is the name given to a new type of wire for electric controls, using numbers instead of color-coding to increase the ease and accuracy of installations and maintenance. Each wire has its code number imprinted in bright red on every inch of the yellow insulation. The numbered wire has two main advantages: the numerals do not wash or wear off, nor become discolored with age; and there is no limit on the number of different numerals available. This wire will be especially useful for equipment using multiple-wire electric controls.—*Midwest Automatic Control Co., 510 Third St., Des Moines, Iowa.*

Blowtorch

A Superheat alcohol blowtorch that will produce a flame of over 2700 F. Such high heat advantage enables this tool to perform silver soldering, brazing, and sweat-fitting work, in addition to all soft-soldering operations. An unbreakable Bakelite Gun Grip handle provides this tool with a cool, comfortable grip plus balance and ease of operation. Other features include a built-in safety stand that enables the torch to be set in various positions on a work bench; a sliding windshield which permits the tool to be used outdoors or indoors with equal efficiency; and it has an adjustable length for performing operations in awkward and tight places.—*Lenk Manufacturing Co., 30–38 Cummington St., Boston 15, Mass.*

Aircraft Circuit Breakers

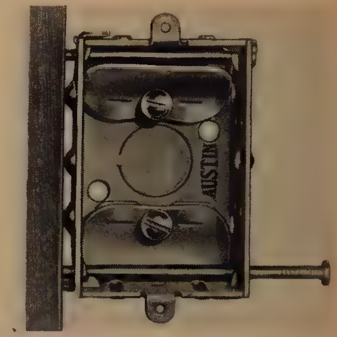
New aircraft circuit breakers for both 28- and 120-volt d-c systems having continuous current ratings as high as 600 amp for the 28-volt breakers and 250 amp for for the 120-volt units. Interrupting ratings for these devices are 12,000 amp for the 28-volt breaker and 5000 amp for the 120-volt breaker. These ratings extend over the full altitude range from sea level to 50,000 ft.



The breakers have been designed with long-time-delay reverse-current trip devices for application in generator circuits and with directional or nondirectional trip devices for other applications. The electrically and manually closed circuit breakers have trip-free mechanisms. The electrically closed breaker includes an antipump control scheme. The weight of the units is kept to a minimum through the use of a welded aluminum cover and a molded plastic base. —*Apparatus Dept., General Electric Co., Schenectady 5, N. Y.*

Switch Box

A greatly improved LR switch box wit nail holes located in box sides eliminate necessity for a mounting bracket, resultin in lower cost and rapid installation. Thre



correctly located nubs facing outward o each side of the box assure the alignmen by keeping box from tilting when naile to the studding. The first nub is ⅞ in from front of box to permit ample adjustment for wallboard or plaster.—*M. B. Austin Co., Northbrook, Ill.*

Dispensing Unit

A redesigned compound and wax dispensing unit offers advantages for suc operations in transformer potting, condense manufacture, brush manufacture, switc manufacture, and other operations callin for the dispensing of compounds and waxe These units are available in capacities c

2 qt to 25 gal. The 2-, 4-, 8-, and 11-q units are as shown in the illustration whereas the 5-, 10-, 15-, and 25-gal unit differ somewhat in construction owing t capacity, but remain essentially the same i mechanical and electrical operation. A units have a special heating element applie directly to the sidewalls and bottom of th inner pot to produce low heat concentratio and give even heat distribution per uni area.—*Sta-Warm Electric Co., Ravenna Ohio.*

Industrial Tape

A line of pressure-sensitive industrial tap will be known as Polyken. This tape i available in an almost unlimited variety o combinations of backing and adhesive materials. Wherever adopted by specific industries, it has created a savings in labo and material. If a stock tape is not available for a specific requirement, one can b made to meet the necessary specifications.—*Bauer & Black, Division of Kendall Co 2500 South Dearborn St., Chicago 16, Ill*

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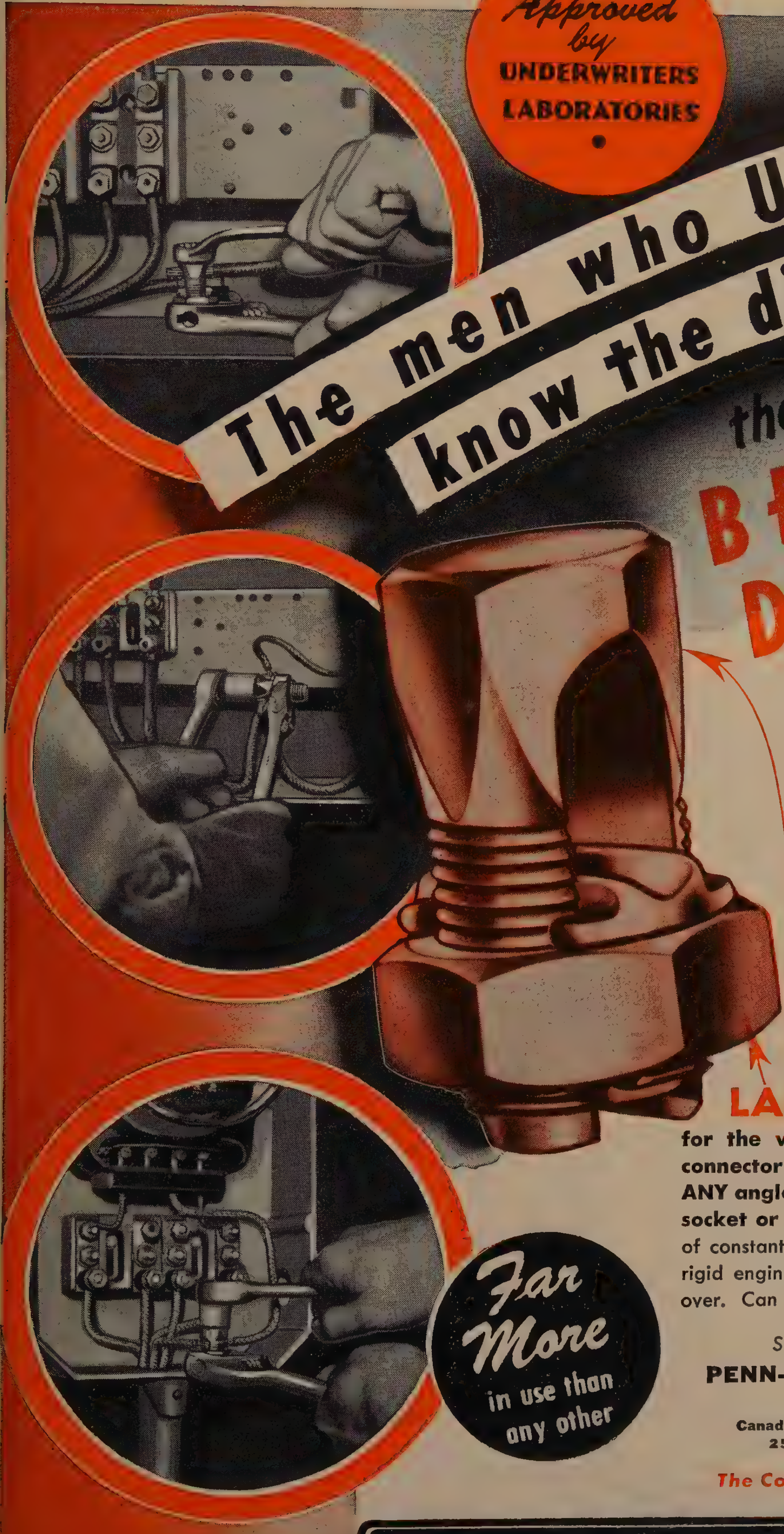

If you have ever spliced wires and cables in real mean locations, you probably are a strong "booster" for Penn-Union Connectors - - -

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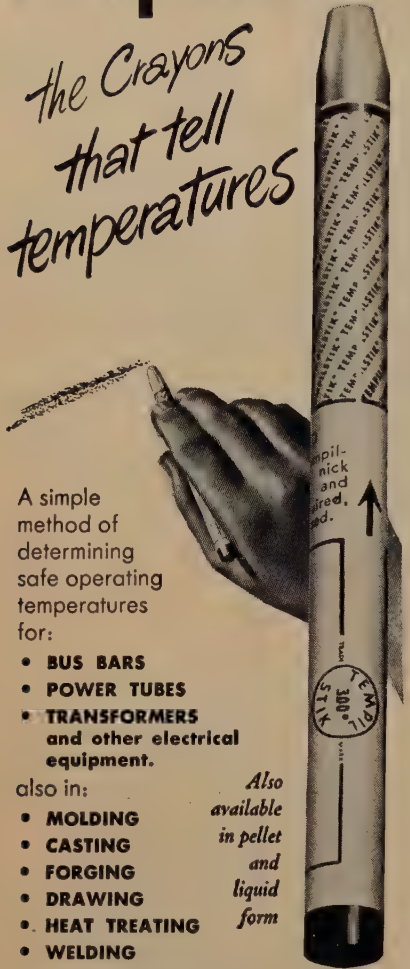
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175	325	650	1200	1750
188	338	700	1250	1800
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TRADE LITERATURE

Bar Screen—A folder giving the distinctive features and specifications of the Thru-Clean Bar screen for removal of trash and large solids from water and sewage in water, sewage, and industrial waste-treatment plants. Photographic views supplement the text. Four pages. Folder No. 2327.—*Link-Belt Co., 307 N. Michigan Ave., Chicago 1, Ill.*

Beama Catalog—A compilation of accurate and attractively presented information on the products of the entire British electrical industry, ranging from heavy power plant to domestic appliances, together with comprehensive data for rapid identification of supply sources. Binding is of waterproof dark blue cloth, and the six main sections are separated by plastic-tabbed dividers. Eight hundred sixty-eight pages. Beama Catalogue 1949–50.—*British Electrical & Allied Manufacturers' Assn., Inc., 36–38 Kingsway, London, W. C. 2.*

Cable—"Selection of Proper Cable Sizes" titles a publication dealing with the method of determining cables and cable sizes of asbestos-varnished cambric cables. Step-by-step instruction is given for calculating load current, voltage drop, etc. for both lighting and motor loads. Convenient reference tables simplify the computations. Twelve pages. Publication No. 19–269.—*General Electric Co., Construction Materials Dept., Bridgeport, Conn.*

Carboloy Tools—An announcement of new lower prices, quantity discounts, and standard package quantities on all standard Carboloy tools, blanks, and diamond products. Sixteen pages. Supplement No. 10 to Catalog GT-200.—*Carboloy Co., Inc., Detroit 32, Mich.*

Commutator and Slip-ring Maintenance—A thorough treatment of the subject emphasizing troubles that arise and how they can be corrected; brushes; and general maintenance procedure. One section describes and illustrates commutator and slip-ring maintenance products. Forty pages. Form No. A-201.—*Ideal Industries, Inc., Sycamore, Ill.*

Compression Distillation—The principles of compression distillation are given together with present industrial applications. Distinctive features of the process are also described. Four pages.—*Arthur D. Little, Inc., Cambridge 42, Mass.*

Co-ordinate Recorder—Description of a system utilizing Type 373 high-speed rectangular co-ordinate recorder to plot voltage, or the logarithm of voltage, as a function of time or displacement angle of a measured element. Also explains its use for measuring antenna patterns, light intensities, sound pressures, etc. Eight pages.—*Airborne Instruments Laboratory, Inc., 160 Old Country Rd., Mineola, N. Y.*

Electrical Tape—Application photographs show some of the uses for Scotch electrical tape No. 27, the tape with glass-cloth backing and thermosetting adhesive that will withstand temperatures up to 300 F. Four pages.—*Minnesota Mining and Manufacturing Co., 900 Fauquier St., St. Paul 6, Minn.*

Flow Instruments and Control Valves—Among the wide variety of instruments described and illustrated are variable-area primary flow meters; frictionless series resonant circuit electrical transmitters; Ratomatic flow-rate recorders; etc. Twenty-four pages. Catalog 50.—*Fischer & Porter Co., Hatboro, Pa.*

Glass Cylinders—A catalog listing a wide range of cylinders, together with prices per piece, is available for the convenience of glass-cylinder users. Six pages.—*Dunbar Glass Corp., Dunbar, W. Va.*

Hot-tinning—Provides working instructions as followed by the British for the production of hot-tinned coatings on fabricated articles and components. Attention is given to plant requirements, and useful hints on plant layout are included. Dip-tinning in its various forms is extensively described in addition to procedures used for cleaning, pickling, etc. One hundred twelve pages. Titled "Hot-tinning" by W. E. Hoare.—*Tin Research Institute, Inc., 492 West Sixth Ave., Columbus 1, Ohio.*

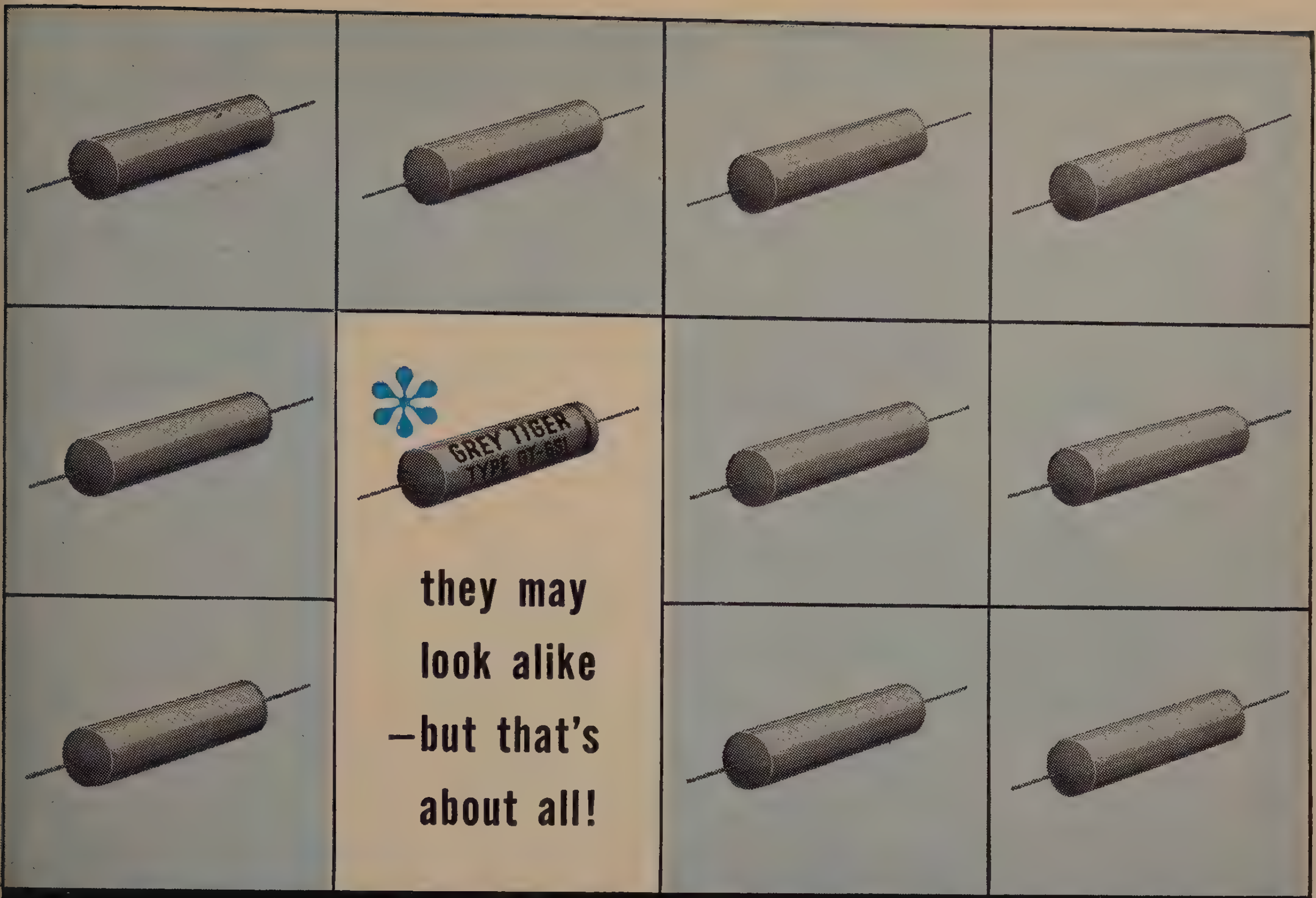
Mercury Switches—The two basic types of switches presented are: mercury-to-electrode and mercury-to-mercury. Their manufacture and testing is described, and typical applications—such as their use in radios, safety controls, burglar alarms, refrigeration controls, business machines, pumps, textile and paper machinery, etc.—are also given. Sixteen pages. Catalog 1343.—*Minneapolis-Honeywell Regulator Co., Brown Instruments Div., Philadelphia 44, Penna.*

Portable Hydraulic Equipment—A folder presenting a complete line of time-saving hydraulic Porto-Power equipment for installing pipe and bending thin-wall conduit. Four pages. Bulletin 50B.—*Blackhawk Mfg. Co., Milwaukee 1, Wisc.*

Power Transformers—Pertinent data on standard RM "repetitive manufacture" transformers including characteristics, standard accessories, prices, outline dimensions and weights, together with optional features and a brief section on application and description. Forty-four pages. GEC-479.—*General Electric Co., Apparatus Dept., Schenectady 5, N. Y.*

Relays—A guide for selecting Double-Diamond equipment to use in signalling and controlling temperature in both laboratory and plant installations. Includes panel-mounted, normally open, and normally closed mercury relays, single- and multicontact thermo-regulators, thermostats, temperature controls, and selector switches. Sixteen pages. Catalog No. 14.—*H-B Instrument Co., 2633 Trenton Ave., Philadelphia, Pa.*

Telemetering—Detailed information on telemetering equipment for electric power distribution and industrial applications includes data on the frequency-type, torque-balance-type, and photoelectric-type telemeters. Connection diagrams for various services are given. Twenty pages. GEA-5233.—*General Electric Co., Schenectady 5, N. Y.*



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but... there's quite a difference in performance, as most engineers know. That's why the overwhelming majority of engineers specify Cornell-Dubilier. There's one way you, too, can be sure of capacitors that won't let you down. That's to specify C-D's. Into the making of each unit goes engineering experience resulting from 40 years of concentration on capacitors. So why take chances? Our engineering-service department will gladly answer your inquiry. Catalogs on request.

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BOOK REVIEWS

(Available books may be purchased through the GENERAL ELECTRIC REVIEW for domestic delivery; none sent on approval.)

ENGINEERING OPTICS

K. J. Habell and Arthur Cox—Sir Isaac Pitman & Sons, Ltd., London (also Pitman Publishing Corp., New York). 1948. xiv+411 pp. $7.50.

This book will be welcomed by those who make use of optical equipment for precision testing and control. It deals at length with such problems as surface examination, profile testing, examination of interior surfaces of long tubes, tests for parallelism, straightness, squareness.

The style of the book will appeal to those with a practical bent, although enough basic theory is included to make understandable the optical systems covered. Of its 400 pages, the first quarter deals with fundamental principles of lenses and lens combinations. Most of the remainder is concerned with microscope and telescope systems and their applications to precision testing and problems of accurate alignment of parts, and to profile examination. Projection methods are thoroughly treated. One chapter deals briefly with interference methods of surface testing.

The book was written in England by English authors, and as a natural consequence descriptions of commercial equipment are largely confined to those in use in that country. The reader will have to be prepared for occasional free shifting of units, for example from the International Candle and Brightness Unit to the Hefner-Candle and the stilb. The following sentence indicates the ease with which the authors apparently slide from one system to another: "The interocular separation varies from 54 mm to 74 mm, so that the lens should be about 3½ inches in diameter." However, in general, units are clearly defined in the text. A few of the minor topics in the book are somewhat loosely discussed, and might as well have been omitted; for example, the page on phosphorescence.

These negligible faults, if faults at all, are scarcely worth noting. The book reads easily, and it will be very useful for those who use optical equipment for maintaining accurate machine control and test, especially for those who want to know how and why the optical parts work.

FRANK J. STUDER

WELDING METALLURGY: IRON AND STEEL (Second Edition)

O. H. Henry and G. E. Claussen (revised by G. E. Linnert)—American Welding Society, New York. 1949. x+505 pp. $2.50.

The first edition of Professor Henry and Dr. Claussen's book, in 1940, required several printings to meet a record demand from all parts of the world.

This new edition has been brought up to date and includes new information on the processes which have been introduced during the past eight years, such as inert-gas metal-arc welding, and more information on the metallurgy of such specific materials as the stainless, heat-resisting, and stainless-clad steels.

Other additions have been made to improve the book as well as bring it up to date; 150 pages have been added and the total number of illustrations increased to 203. A short bibliography has been placed at the end of each chapter, to suggest sources of additional information on the particular subject covered by that chapter. An extensive index has been added to make the book more useful for reference purposes. Questions on each chapter are provided at the end of the book for use in schools or for home study.

The language has been kept very simple and is easy to understand. In the first chapters the fundamentals of metallurgy are described for those having no previous knowledge of the subject. The welding metallurgy of specific materials and the effect of different elements are covered in later chapters, so that the book can be useful for both technical and nontechnical readers.

R. W. CLARK

RADIO AMATEUR'S HANDBOOK (26th Edition)

American Radio Relay League, Inc., West Hartford, Conn. 1949. 736 pp. $2.00 ($2.50 outside U.S. and Canada).

This handbook has become such a familiar publication that one's first impulse is to say of it simply that it is too well known to need a review. On the other hand, its very excellence would deserve mention—regardless of the fact that with its present edition the Handbook has attained the stature of 2,000,000 copies during the twenty-three years since its first appearance.

In general design, the twenty-sixth edition resembles its immediate predecessor; consequently it possesses a high degree of practical usefulness. This is achieved first of all in the simplicity of its presentation of basic principles and then in the step-by-step development of their embodiment in good, workable designs. These essential items of transmitting and receiving equipment are presented by diagram and photograph in an unusually effective manner; and a generous assortment of new equipment is covered, including much for ultra-high-frequency use.

The needs of the nonprofessional are of course kept always in mind; but the information is of such high grade and such profusion that the book is a compilation of technical information that is of more than ordinary usefulness. Pertinent data are well selected, classified, and grouped for convenience. Many of the listings and tabulations are remarkably extensive and useful.

Along with the equipment chapters are those dealing with the progress of the art of amateur radio communication, its requirements, and techniques. The lively, refreshing style of presentation as well as the breadth of content will make this edition welcome to amateur and veteran operator alike.

J. E. GLICK

SILICONES AND OTHER ORGANIC SILICON COMPOUNDS

Howard W. Post—Reinhold Publishing Corp., New York. 1949. 230 pp. $5.00.

The purpose indicated by the author and publishers is to organize and correlate here the great mass of material now available in chemical literature relating to silicone resins and other aspects of the organic chemistry of silicon. This reviewer believes that the use of the word "resins" by the publisher was an editorial oversight. Actually, the book gives an organized presentation that is far more comprehensive than anything recently published on the organo-silicon compounds.

This work of Professor Post's should provide a useful reference book for laboratory worker, lecturer, and commercial producer and consumer.

A review of the early work of Frederick S. Kipping and others provides an adequate introduction to the halogenated silanes and the organo silicones. There is a fairly comprehensive review of pertinent literature and patent references. The book is adequately provided with footnotes and bibliography.

There is an extensive chapter on the uses of the polymerized oxosilanes, which has been compiled from scientific articles, patent literature, and the commercial literature of the various producers of silicone chemicals. This section is deserving of a careful re-examination by the author and editor prior to subsequent editions.

The nomenclature of the silico-organic chemistry is treated in an excellent chapter. Since this is a new branch of science that is slowly creating its own new language, the workers in this field will do well to familiarize themselves with the nomenclature that is being adopted as standard.

Finally, the book contains approximately 30 pages which list organo-silicon chemicals and their physical properties. This is followed by an author index which should prove useful to research workers in the field.

J. W. RAYNOLDS

PHOTOELECTRICITY AND ITS APPLICATIONS

V. K. Zworykin and E. G. Ramberg—John Wiley & Sons, Inc., New York. 1949. xii+494 pp. $7.50.

(Replaces 2nd edition of *Photocells & Their Application*, by Zworykin and E. D. Wilson.)

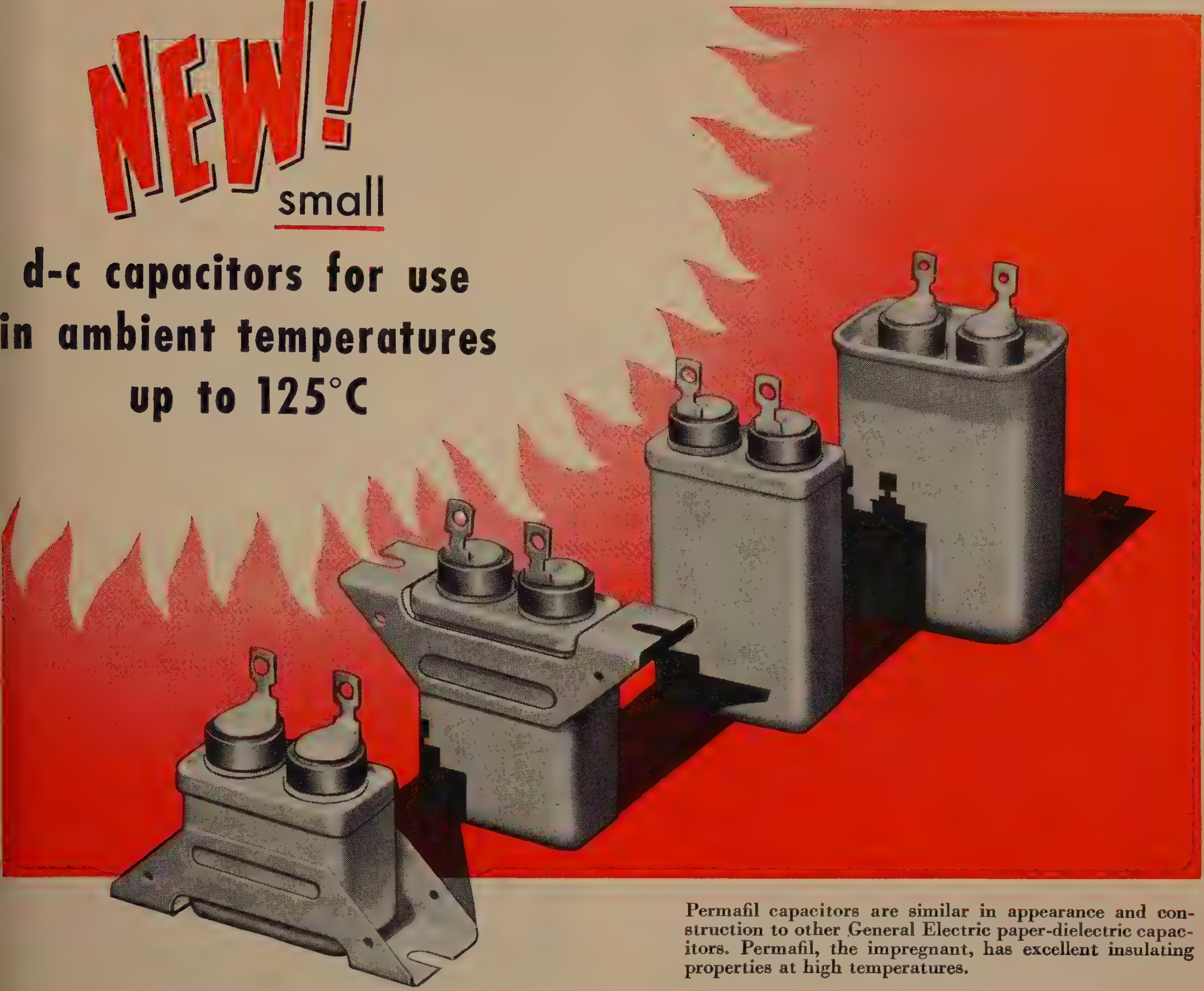
A complete list of the applications of photoelectric devices would extend not only into virtually every branch of science and technology, but also into important, or even vital, phases of our everyday life; which is equivalent to saying that this book will find extremely wide use among scientists and engineers, for indeed it serves as an excellent introduction to the entire subject. Every type of photoelectric device is covered, including (to name a few) television pickup devices and sound motion picture equipment, industrial applications, and scientific measurement apparatus.

The book has two main parts, as implied by the title: The first, beginning with a short history of the early developments, treats the principles and preparation of practically all types of photoelectric devices; the second covers circuit design and application of these devices. Naturally, with such a wide treatment of the field, the authors have had to limit their aim. Hence, the emphasis is on the practical aspects, with theory given for the most part only by means of footnotes and references. The latter, however, are quite extensive, adding greatly to the usefulness of the book.

The treatment of principles presupposes only an elementary knowledge of mathematics. Furthermore, design and technique are included for those unfamiliar with electronics or vacuum procedures. Hence, the book will be extremely useful as a handbook on the design and application of photoelectric devices.

I. C. ABRAHAMS

NEW! small d-c capacitors for use in ambient temperatures up to 125°C



Permafil capacitors are similar in appearance and construction to other General Electric paper-dielectric capacitors. Permafil, the impregnant, has excellent insulating properties at high temperatures.

General Electric announces a new line of Permafil d-c paper-dielectric capacitors designed especially for operation in high ambient temperatures. They require no derating for temperatures up to 100° C and can be used up to 125° C.

Hermetically sealed in metallic containers, these new units are available in case styles 61, 63, 65 and 70, as covered by Joint Army-Navy Specifications JAN-25-C, in ratings of 0.10 to 4.0 muf 600-, 1000- and 1500-volts. Permanently sealed silicone bushings are provided on all types.

Permafil capacitors were developed to provide suitable components for the many new applications involving continual operation at ambient temperatures above 85°C—another example of capacitors "designed for the job" by G-E engineers. For further information on these or on capacitors for other applications, write *Capacitor Sales Division, General Electric Company, Pittsfield, Mass.*

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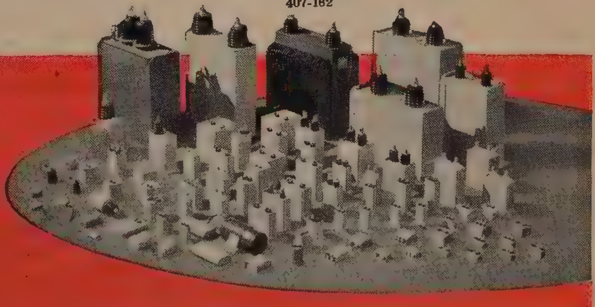
AND MANY OTHER APPLICATIONS



LIBRARY NOTES

ON ARTICLES IN OTHER TECHNICAL JOURNALS

BRAZING

How to Braze Aluminum, by Floyd A. Lewis, *Iron Age*, July 7, 1949; v. 164, pp. 78-82.

Types of aluminum which can be brazed, methods of brazing, types of filler material, fluxing procedures, and cleaning are presented.

Induction Brazing With Silver Alloys, by Frank W. Curtis. *Steel*, July 18, 1949; v. 125, pp. 82-84, 124-126.

Speed with which joining temperatures can be obtained, uniformity of heat generation, and economy in heating costs are some of the benefits reported from the use of high-frequency induction-heating methods.

New Brazing Method for Joining Nonmetallic Materials to Metals, by C. S. Pearsall. *Mat. & Methods*, July 1949; v. 30, pp. 61-62.

Describes one-step brazing process by which ceramics, carbides, and other nonmetallics can be joined to each other or to metals, giving a strong, lasting bond.

CALCULATING INSTRUMENTS

Mechanical Computing Mechanisms, by Robert R. Reid and Du Ray E. Stromback. *Prod. Engng.*, Aug. 1949; v. 20, pp. 131-135.

First article of a series on a systematic approach to the designing of mechanical analog computers.

EXTRUSION

Applications of Hot Extrusion Methods, by Claud L. Stevens and Gustav Vennerholm. *Steel Processing*, July 1949; v. 35, pp. 362-367.

Outlines briefly some of the steps that lead up to the final adoption of the hot extrusion method for producing certain types of steel forgings.

Cold Extrusion of Steel, by T. E. Lloyd and E. S. Kopecki. *Iron Age*, Aug. 4, 1949; v. 164, pp. 90-105.

Applied to ferrous metals, cold extrusion may well alter some of the fundamental concepts of metal working, fabrication, and product design.

MEASURING INSTRUMENTS

Precision Automatic Electrometer, by N. T. Seaton. *Rev. of Sci. Instr.*, July 1949; v. 20, pp. 500-503.

A triple-range portable electrometer suitable for the precision measurement of currents of the order 10^{-11} to 10^{-14} amp is described.

Stable Ten-light Decade Scaler, by Richard Weissman. *Electronics*, May, 1949; v. 22, pp. 84-85.

Describes a six-stage ten-light decade counter using by-passed cathodes and special coupling circuits to ensure positive trigger action for counts up to 200,000 per second.

PLASTICS

Molded Laminated Machine Parts, by David Ritchie. *Mach. Design*, June 1949 v. 21, pp. 111-113, 178.

Shows how they offer properties on pa with stock-form laminates at lower cost than machined laminates.

Selected Case Histories in Plastic Applications, by J. Harry DuBois. *Elec Mfg.*, June 1949; v. 43, pp. 84-87, 174, 176

Problems in plastic part design analyze here show that best results are obtaine from a synthesis of the skill and knowl edge of product engineer, stylist, custom molder, and materials supplier.

RUBBER

Conductive Rubber as a Component by B. W. Bender and J. F. Schreiber *Elec. Mfg.*, Aug. 1949; v. 44, pp. 96-101 188, 190.

Gives fundamental information from which to appraise both its usefulness and its limitations as a component in electrical equipment.

WIRE DRAWING

Process for Hot Drawing Wire, by Rheinhold Schempp. *Steel*, June 13, 1949 v. 124, pp. 116, 118.

Description of a process giving excellen physical properties and eliminating repeated annealing, pickling operations.

Correction Please!

WELDRAWN* Beryllium Copper Tubing
(Welded and Drawn)

★ *is not expensive...*
★ *offers advantages not found in any other alloy!*

All too frequently Beryllium Copper tubing has been dismissed as "too costly."

We at Superior Tube Company want to correct that erroneous impression—Superior WELDRAWN (welded and drawn) Beryllium Copper is not priced out of the market.

In fact, Superior Beryllium Copper tubing often *lowers* the *installed* cost of a part, reduces assembly time, or adds greater service life to a component—all factors to be considered in these competitive days.

Don't miss the opportunities which Superior Beryllium Copper tubing may hold for you—uninvolved heat treatment for hardening, high tensile strength, fatigue resistance, low drift, good formability, corrosion resistance, and electrical conductivity if you need it. *Get full particulars on Beryllium Copper small tubing by Superior and compare! Write today for Data Memo #7.*

THE BIGGER NAME IN SMALL TUBING Superior

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GENERAL ELECTRIC REVIEW
Schenectady 5, N. Y.

SILVER CONTACT SURFACES

to eliminate oxidation troubles

AT NO INCREASE IN PRICE

POWER CONNECTORS

SILVER is used exclusively on *all* G-E connectors because it allows power to flow between conductor and connector with no losses or overheating. This helps eliminate annoying oxidation problems that are a definite maintenance item. The more a connector heats up, the more it oxidizes; and the more it oxidizes, the more it overheats. This vicious cycle continues until the connector fails.

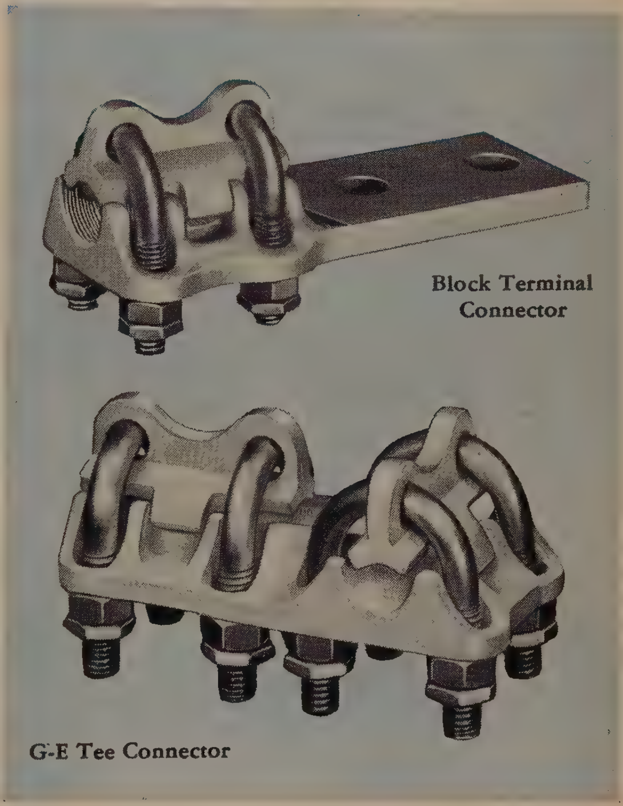
CORRECT MATERIAL for the job is another feature assuring you that G-E connectors "run cool." The composition of the alloy used permits the connectors to carry the maximum current of any conductor on which they are used . . . with no losses and without overheating. By using G-E connectors you're assured of long connector life because of silver contact surfaces and ample current-carrying capacity; double safeguards against oxidation troubles and they don't cost you a cent extra.

CHECK THESE ADDITIONAL FEATURES . . .

SERRATED CONTACT SURFACES give extremely high pull-out strength and a permanent, high-conductivity joint that will resist vibration and give positive pressure on the conductor at all times.

NON-CORRODIBLE HARDWARE is of high-strength bronze alloy that gives tight and trouble-free service. G-E connectors will not twist, distort, or season crack.

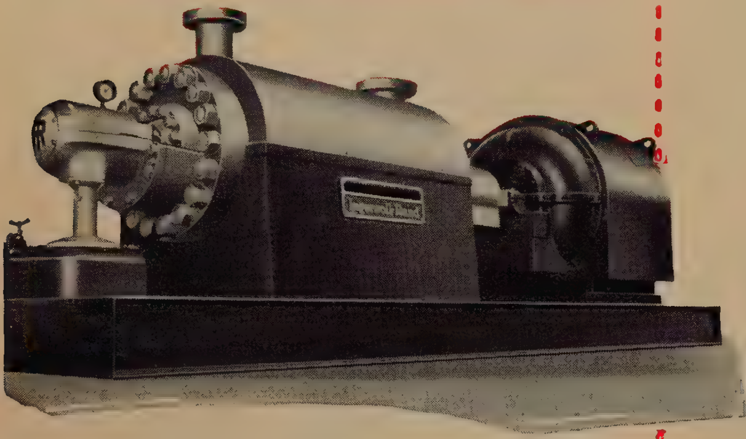
INTERLOCKING SIDES confine the strands of the conductor within the conductor enclosure, thus obtaining full advantage of the conductor's current-carrying capacity.



Place an order today with your G-E sales representative and start realizing the many benefits to be gained by using this new line of General Electric connectors. Also, write for a copy of bulletin GEC-400 that contains 40 pages of valuable information on G-E connectors, and see for yourself how easy they are to order. Write to *Apparatus Department, Section 856-52, General Electric Company, Schenectady 5, New York.*

GENERAL ELECTRIC

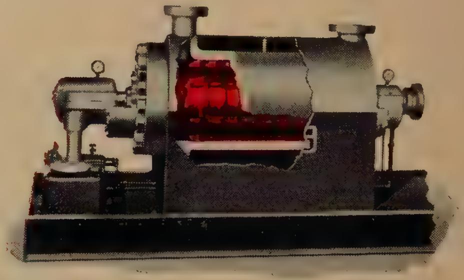
HERE'S WHY Ingersoll-Rand BOILER-FEED PUMPS are FIRST CHOICE for really HIGH PRESSURES



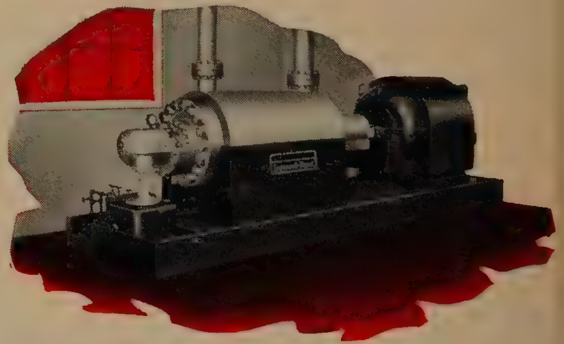
When so many leading Central Stations repeatedly specify Ingersoll-Rand boiler-feed pumps for the highest operating pressures in use today, you can be sure there are good reasons for this preference. Here are three of them—*dependability, ease of maintenance,* and *appearance*—all important considerations in the modern, high-pressure steam generating plant.

I-R high-pressure boiler-feed pumps, Class CHTA and CHTB, are multi-stage, single-suction, diffusor-type units, built for discharge pressures of from 1000 to 3000 psi—in capacities to 2800 gpm at temperatures up to 800° F. But *whatever* pressure or capacity you need, Ingersoll-Rand can supply a boiler-feed pump for the job. I-R engineers will be glad to help you select the pump that best meets all of your specific requirements.

DEPENDABILITY is probably the most important single requirement in all central station equipment. And here, I-R double-case boiler-feed pumps have chalked up a record that speaks for itself. Many of these high-pressure units have been in service for over 12 years—with little or no attention! And more than 40% of the units sold are on *repeat* orders—from users who have already proved this dependability in their own plants.



EASIER MAINTENANCE, and less of it, is an inherent feature of the new I-R Class CHTA and CHTB pumps. They are of "double-case" construction which permits maximum accessibility and greatly simplifies regular maintenance procedure. You save hours, or even days of "down-time" on dismantling and assembly operations too, because the entire inner casing assembly can be removed as a unit in a surprisingly short time.



APPEARANCE is becoming an increasingly important factor in the modern Central Station. And the sleek, stream-lined design of I-R boiler-feed pumps is entirely in keeping with the trend in modern equipment. Many of the lubricating system components have been integrated into one compact assembly, thus eliminating much external piping. Sheet metal lagging over the casing blends in with the main pump support.

***FOR COMPLETE** information on Class CHTA and CHTB high-pressure boiler-feed pumps call the nearest Ingersoll-Rand branch office. Ingersoll-Rand manufactures all types and sizes of centrifugal pumps.*

IR

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GENERAL ELECTRIC *Review*

DECEMBER, 1949
Vol. 52, No. 12

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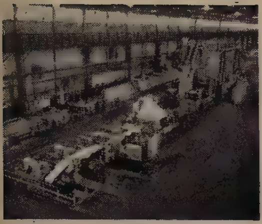
Associate Editor



THE COVER

A large installation in which protective atmosphere furnaces in two processing lines are engaged in the continuous bright-annealing of steel strip and the treating of its surfaces preparatory to galvanizing. The roller-hearth furnace equipment in the rear handles thin strip, while that of the tower-type in the foreground handles relatively heavy strip. The process includes but one of the many interesting new applications of protective atmospheres described in this issue in the serial on p. 46. Others will follow.

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ELECTRONICS

Designers

A LINE-VOLTAGE STABILIZER

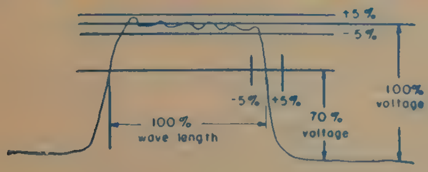
SO SMALL . . .

. . . it mounts on a radio chassis

These 15-, 25-, and 50-va G-E voltage-stabilizer units are only a little over 2 inches high and about 9 inches long. They'll mount easily on a medium-sized radio or electronic instrument chassis and will give you an even, non-fluctuating 115 volts for your equipment whether your line voltage is 95 or 130. A special transformer circuit provides a stabilized output voltage within 1% of 115 volts for fixed, unity-power-factor loads.

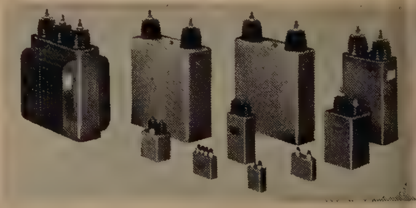
Continuous operation under conditions of short or open circuits will not damage the stabilizer in any way. Since there are no moving parts, there is little maintenance to worry about. For complete information on voltage-stabilizer units of all sizes from 15-va to 5000-va, write for Bulletin GEA-3634.

AN EASY WAY TO PRODUCE SQUARE WAVES



Specially designed G-E Type-E networks will produce impulses which have definite, known energy contents and durations, and thus are ideal for converting a-c or d-c charging voltages into approximately rectangular square waves. These networks consist of capacitor and coil sections adjusted to close tolerances and hermetically sealed in single metal containers.

G.E. helped meet wartime radar demands with thousands of these units and now offers them for commercial use. They are available in a wide range of designs, impedances, ratings, and sizes for pulse lengths of 0.1 to 40 microseconds. See Bulletin GEA-4996.

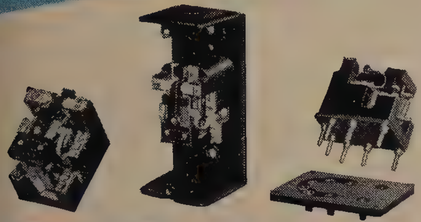


GENERAL ELECTRIC

667-3

Digest

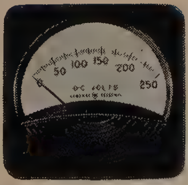
TIMELY HIGHLIGHTS ON G-E COMPONENTS



HEAVY-DUTY RELAYS THAT MOUNT 3 WAYS

This versatile, general-purpose, heavy-duty, a-c relay unit is available in three mounting arrangements: front connected, back connected, or plug-in connected. All three mounting types are available in open or enclosed models and are furnished in spst, dpst, or dpdt circuits. Heavy, long-lasting silver contacts carry 10 amps continuous. Normally-open forms make or break 45 amps; normally-closed forms make or break 20 amps. Relay coils come in 12-, 24-, 115-, or 230-volt, 60-cycle a-c sizes. D-c units are available in similar models. For full details see GEC-257.

ACCURATE BUT RUGGED



The new, modern-looking, easy-to-read 2½ inch G-E instrument line is improved inside as well as outside. A single, self-contained mechanism supported on an extremely strong Alnico magnet assures permanent alignment even under the most adverse operating conditions. This high-gauss Alnico magnet permits the use of a large air gap with a consequent smoother, non-sticking action. The greater torque-to-weight ratio means better damping and allows the use of heavier vibration-resisting pivots. Accuracy is 5% of full scale on rectifier types, 2% on all others. For complete details, send for Bulletin GEC-368.

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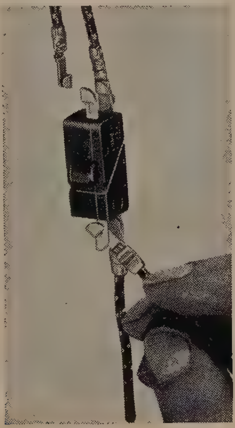
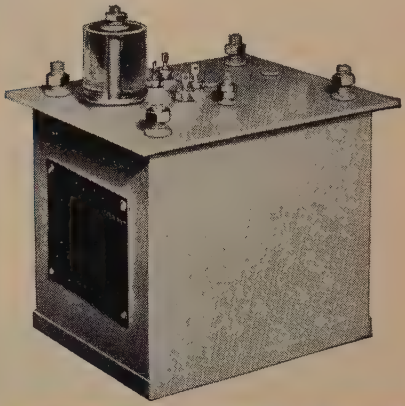


For your convenience there are screw-terminal and soldering-lug types as well as this special quick-connect unit. Send for Bulletin GEA-4888.



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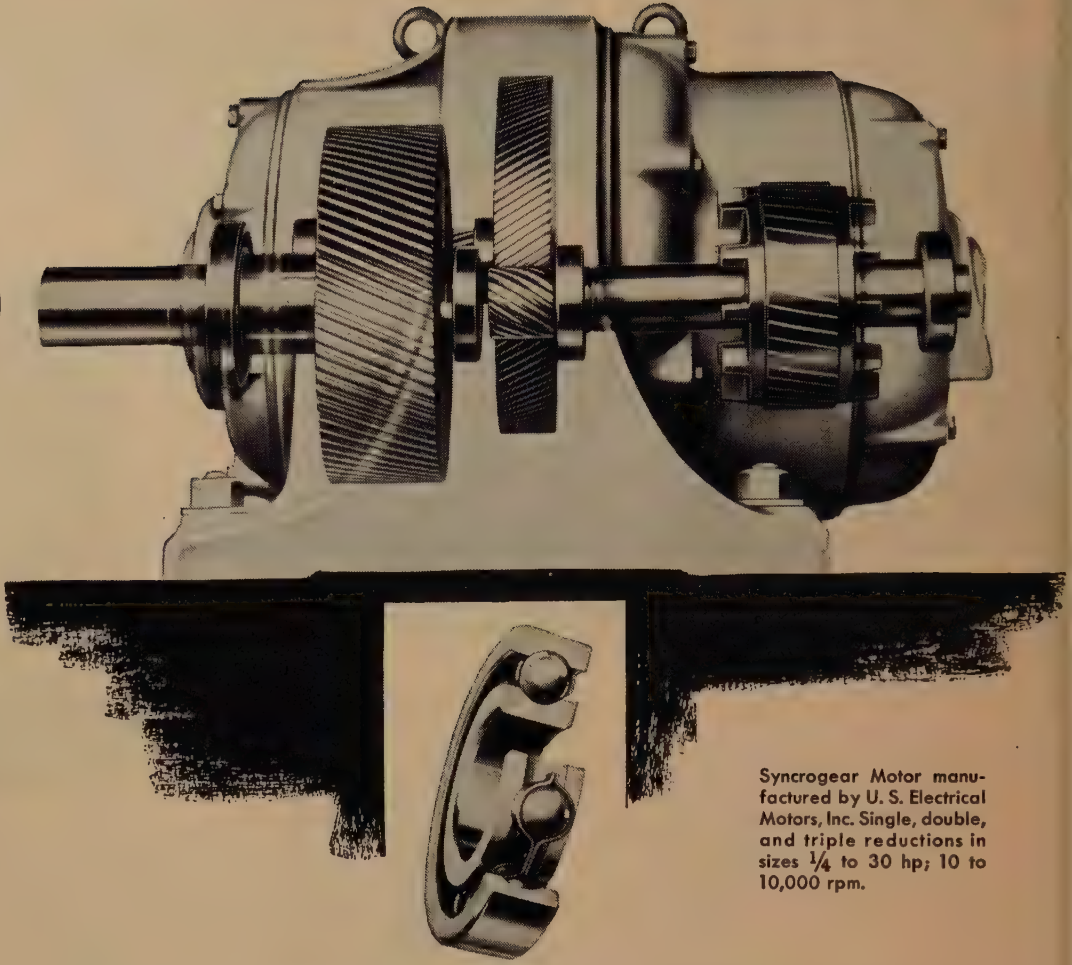
10 rpm



Syncrogear Motor manufactured by U. S. Electrical Motors, Inc. Single, double, and triple reductions in sizes 1/4 to 30 hp; 10 to 10,000 rpm.

or 10,000 rpm . . . makes no difference to

SKF SINGLE ROW DEEP GROOVE BEARING

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Electrical Equipment Bearings engineered by **SKF**

When temperature goes up

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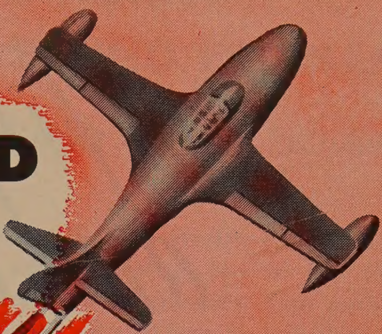

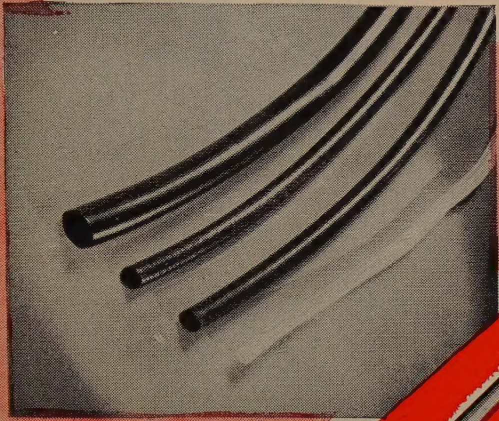

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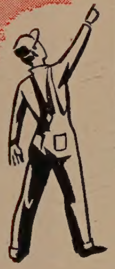

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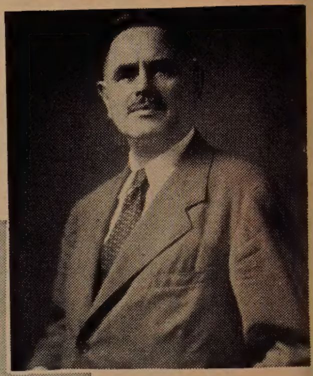

THIS LABORATORY IS DEDICATED
TO THE MEMORY OF
HENRY KREISINGER
ENGINEER - SCIENTIST - TEACHER
A PIONEER WHO MADE MAJOR CONTRIBUTIONS TO THE
SCIENCE OF FUEL BURNING AND STEAM GENERATION.
A PROFOUND THINKER WHO SOUGHT ONLY TO FIND
THE TRUTH AND APPLY IT TO THE ADVANCEMENT
OF PRACTICE IN THE FIELD HE SERVED.
A SIMPLE, MODEST AND LOVABLE MAN.
DIRECTOR OF RESEARCH
COMBUSTION ENGINEERING COMPANY, INC.
1920 - 1946

Kreisinger Development Laboratory, Chattanooga, Tenn.

"To find the truth and apply it . . ." was the lifelong objective of Henry Kreisinger, in whose honor the new Combustion laboratory, pictured above, has been named. An immigrant to this country at the age of fifteen, his story exemplifies the traditional opportunity America affords not only to her native citizens but to her adopted sons as well. Beginning as an apprentice in a machine shop in 1891, he had accumulated enough money by 1900 to begin his college career. By 1913 he had risen to the position of Supervising Engineer in the Fuel Section of the Bureau of Mines. Seven years later he left the Bureau of Mines to engage in research work for Combustion. Long prior to his death in 1946, his work had brought him international recognition as a leading authority in the field of fuel burning and steam generation.

His vision widened the horizons not only of his own organization, but of the whole power field. His pioneering work in the field of pulverized coal firing and water-cooled furnace walls was an outstanding achievement that initiated the widespread use of pulverized coal in power stations throughout the world. This work was recognized in 1943 by his selection for the Percy Nicholls award, a joint award of the American Society of Mechanical Engineers and the American Institute of Mining Engineers for "notable scientific or industrial achievement in the field of solid fuels."

Combustion's long-range research and development program, under the direction of Mr. Kreisinger, contributed importantly to the advanced engineering features characteristic of the complete C-E line of steam generating, fuel burning and related equipment. And because today's experiment may well be tomorrow's standard practice, Combustion is constantly exploring new frontiers at its laboratories where the successors to Mr. Kreisinger devote their talents to carrying on his objective "To find the truth and apply it." B-336

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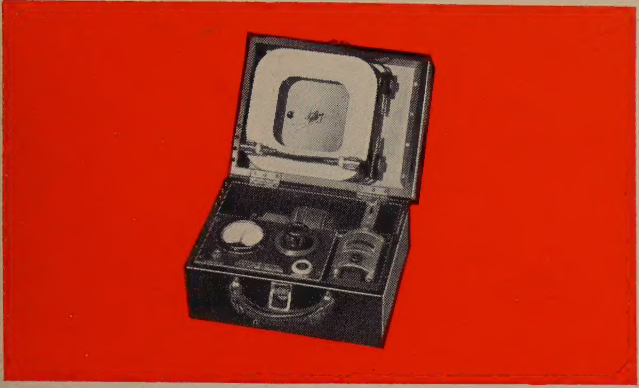

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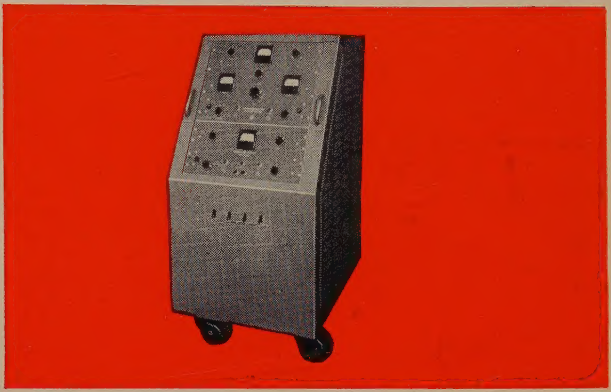
GENERAL ELECTRIC

You may find that General Electric engineers can help you by recommending one of the many G-E stock devices and instruments. Your problem, especially if it is one common to industry, may even justify developing new equipment. Send the coupon today to Apparatus Department, General Electric Company, Schenectady, N. Y.



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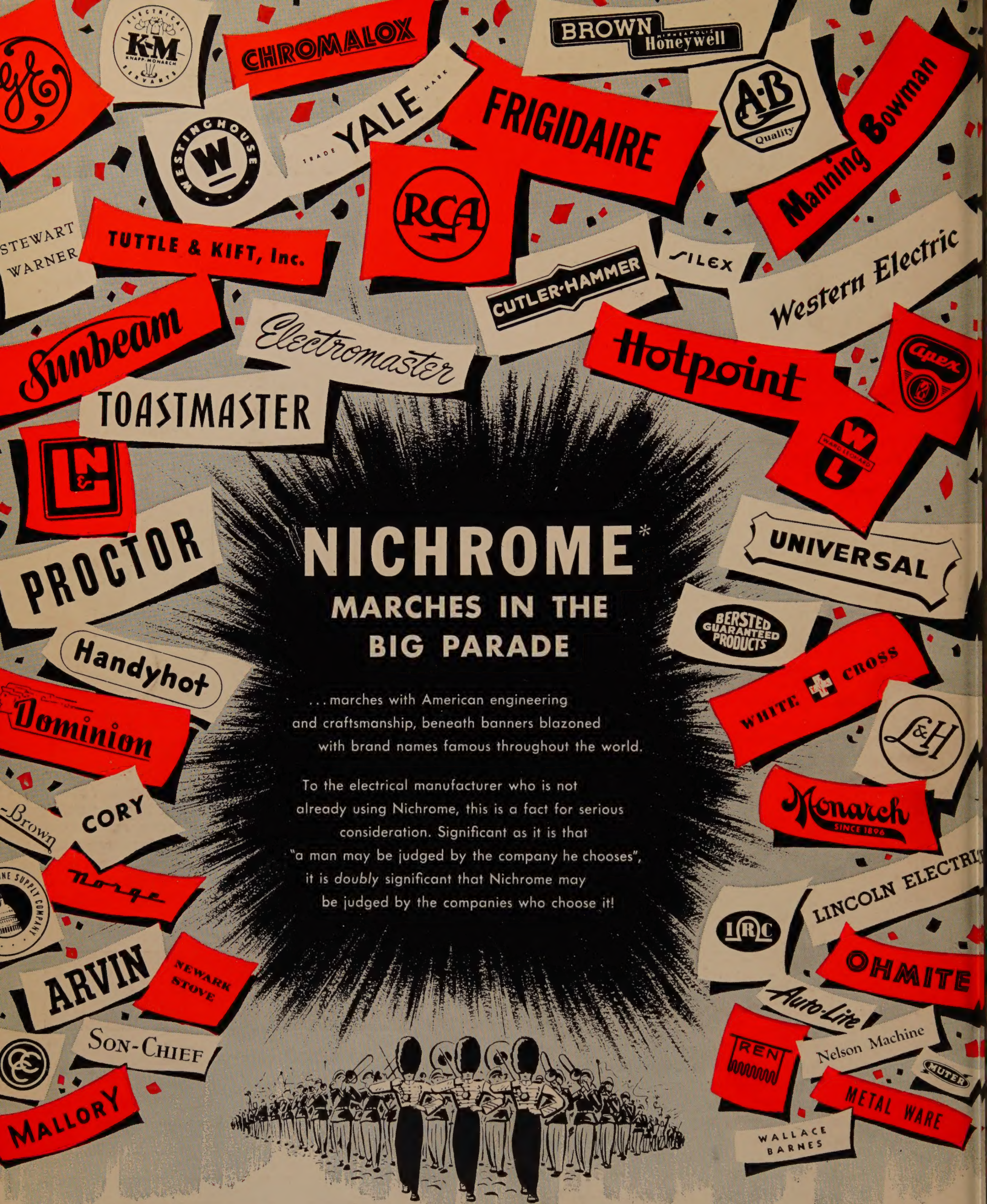

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MARCHES IN THE BIG PARADE

. . . marches with American engineering and craftsmanship, beneath banners blazoned with brand names famous throughout the world.

To the electrical manufacturer who is not already using Nichrome, this is a fact for serious consideration. Significant as it is that "a man may be judged by the company he chooses", it is *doubly* significant that Nichrome may be judged by the companies who choose it!

50TH YEAR
SPECIAL PURPOSE ALLOYS SINCE 1899
D H
TRADE MARK REG. U. S. PAT. OFF.
1899 - 1949

Nichrome is manufactured only by

Driver-Harris Company

HARRISON, NEW JERSEY

BRANCHES: Chicago, Detroit, Cleveland, Los Angeles, San Francisco
Manufactured and sold in Canada by
The B. GREENING WIRE COMPANY, LTD., Hamilton, Ontario, Canada

Nichrome
IS THE VERY HEART OF GOOD ELECTRICAL APPLIANCES

Most of the insignia above are Reg. T. M. of their companies